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DEVELOPMENT AND EVALUATION OF SELECTIVE ADDRESS BEACON (SAB) SYSTEM

FINAL REPORT

S.H. Kowalski

August 1978

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DEPARTMENT OF TRANSPORTATION

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Avionics designs supporting the concepts are developed and avionics cost estimated for the air carrier and general aviation classes of aircraft.

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SUMMARY

ARINC Research Corporation is under contract to the Federal Aviation Administration (Contract DOT-FA76WA-3788) to assist in the development and evaluation of technical and cost factors that will affect the upgraded third-generation air traffic control system. One effort under this contract was an investigation into the technical and economic feasibility of developing a selective address beacon (SAB) system to reduce or eliminate the loss of surveillance data caused by synchronous garble of transponder replies.

Synchronous garble is a phenomenon that occurs when two transponder-equipped aircraft are at a slant range of 1.7 nautical miles from each other and both are within the beam of the interrogating radar. Under those circumstances, the transponder reply pulses overlap and cause the receiving radar to lose surveillance data.

ARINC Research Corporation reviewed the severity of the synchronous garble problem, the efforts of the government and industry to improve surveillance, and potential solutions that could be developed to provide either interim relief or long-term correction of the problem. The result of the review process was the identification and development of two selective address concepts; one that could be introduced and implemented in the near future, thereby providing an interim solution before the deployment of DABS, and the second which would provide long-term solutions to synchronous garble problems in the event DABS is not deployed.

This report presents the results of the investigation into synchronous garble problems, the designs of selective addressing concepts intended to improve aircraft surveillance, the effect of the concepts in the operational environment, and the costs associated with system introduction and implementation.

Two concepts intended to reduce synchronous garble problems were evaluated -- the one-out-of-eight and the 4096 SAB systems. The one-out-of-eight system discriminates between aircraft on the basis of the last digit of the assigned transponder codes and provides a seven-fold improvement in surveillance when aircraft are in a situation holding the potential for synchronous garble. The system is intended to provide a degree of improvement in crowded terminal environments and must be viewed as an

interim solution. The 4096 SAB is a full selective address concept providing discrete interrogations to all aircraft with assigned unique codes. The system was designed to facilitate early implementation by minimizing airborne and ground modifications, but has the capacity to handle the traffic densities expected in the 1980s.

The cost of avionics required for each of the two concepts was developed for both existing and new aircraft. Changes to the existing fleet, assumed to be equipped with ATCRBS transponders, were limited to modification packages that would be added as adapters to existing avionics. New airframes would be equipped with SAB transponders providing all the presently required ATCRBS features plus the selective address capability of SAB. Avionics costs for the adapters and new transponders were developed for ARINC-type equipment that would be used by air carriers and operators of high-performance (capable of speeds over 250 knots) general aviation aircraft. Avionics costs for the less stringent requirements of the low-performance general aviation aircraft were limited to new transponders for the 4096 SAB concept on the basis of operational considerations and present procurement practices in the general aviation community. Table S-1 presents a summary of the cost of avionics required to implement the SAB concepts in the three classes of users.

The cost of implementing the SAB concept was evaluated with the assistance of the economic analysis model developed by ARINC Research to identify the costs of the first year of ownership to the private aircraft owner and fleet operators. Installation costs, recurring and nonrecurring logistics costs, and complementary equipment (e.g., the required antennas) costs were identified and evaluated by the model on the basis of data developed in this study and available from past studies.

Table S-1. ACQUISITION COST OF SAB AVIONICS

Equipment	Cost (in dollars) by User Category		
	Air Carrier	High-Performance General Aviation	Low-Performance General Aviation
One-Out-Of-Eight System			
SAB Adapter	572	743	N/A
SAB Transponder	4144	5388	N/A
4096 System			
SAB Adapter	1201	1561	N/A
SAB Transponder	4558	5926	917
Control*	516	516	N/A
Antenna*	63	75	13

*From manufacturers' price lists.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The Federal Aviation Administration (FAA) has been evaluating various surveillance concepts intended to reduce synchronous garble of replies to Secondary Surveillance Radars (SSR) in dense traffic areas. Among the most promising solutions is the Discrete Address Beacon System (DABS), which selectively interrogates each aircraft within line of sight of the radar. Improvements to present Air Traffic Control Radar Beacon Systems (ATCRBS) such as monopulse techniques show a high degree of promise in position location and synchronous garble reduction because of the narrowed beam widths used by the radars. However, these concepts are still in the development stages and are not expected to be available for wide implementation until the mid-1980s. In the meantime the problem caused by synchronous garble increases with the growth of the aviation community.

The Office of System Engineering Management (OSEM), in response to the requirements outlined in the Review of Upgraded Third Generation Air Traffic Control System Developments, has tasked ARINC Research Corporation, under FAA Contract DOT-FA76WA-3788, to investigate alternate concepts that could be readily implemented and that will reduce the synchronous garble problem to a tolerable level, based on present and near-future traffic densities. The Selective Address Beacon (SAB) system developed by the United Kingdom (ADSEL) provides a basis for the development of alternative concepts intended to reduce synchronous garble and has been used accordingly in this study.

1.2 CONTRACT OBJECTIVES

The primary objective of the contract effort is to develop and evaluate design and cost data for avionics equipment that can be used with existing ATCRBS systems and that will provide position location to air traffic controllers in busy airspace having the potential for synchronous garble. A secondary objective is to identify the modifications to ground equipment that will be required if the concept under investigation is implemented.

The design associated with each alternative concept is sufficiently detailed to allow engineering models to be developed for test and evaluation of the concept. However, the designs are based on expected large production manufacturing techniques and reflect configurations that would probably be produced by present ATCRBS transponder manufacturers.

The costs associated with acquisition, installation, operation, and support of each type of equipment have been addressed in this study and have been combined to establish the first-year cost of ownership to both the individual owner and the fleet operators. As a result, separate cost data have been developed for general aviation and commercial air carriers.

To provide fair and expeditious cost evaluations, the contract has required that the same ground rules used in earlier ARINC Research evaluations of system costs be applied to this contract effort. ARINC Research participation in the air-derived collision-avoidance system and the DABS/IPC system cost studies has resulted in the formulation of the necessary assumptions concerning such items as aircraft retrofit requirements, maintenance scenarios, aircraft population data for periods of interest, and classes of aircraft that would be likely candidates for the air carrier version or general aviation version of new avionics equipments.

1.3 TECHNICAL APPROACH

This report is concerned with the development and estimated cost of a selective address system that can be readily and cost-effectively implemented in selected categories of aircraft and that will reduce synchronous garble problems either in dense traffic environments or when the relative positions of aircraft cause loss of surveillance data.

To accomplish the desired goals, the study included a review of the cause of synchronous garble and familiarization with equipment carried on commercial and general aviation aircraft and with the operation of the secondary surveillance system -- especially in the terminal area environment. In addition, solutions to the problem proposed by both federal agencies and industry were reviewed. The early developments of the British Address Selective (ADSEL) system together with the recent joint development of the DABS/ADSEL data-link surveillance system provided a basis for the concepts proposed in this study for the selective address beacon system.

The candidate concepts, described in detail in Chapter Two, were developed using techniques that could be readily implemented with a minimum of both avionic and ground modifications and would have no adverse effect on the operation or reliability of the existing surveillance systems.

The concepts were subjected to an operability evaluation to judge the effectiveness of each in reducing or eliminating synchronous garble and to determine the system's capacity in terminal environments when constrained by existing surveillance system parameters and operational procedures.

Once the concepts were identified, the designs were developed and adapted to the appropriate class of avionics for the different user communities. Costs associated with equipment manufacturing and distribution were estimated; from those estimates, the expected acquisition costs of the systems by both private aircraft owners and fleet operators were calculated. These cost estimates were developed by formulating detailed avionics designs and computing the essential production costs from the required numbers and types of electronic components included in each design. Reliability prediction techniques were applied to the designs to provide the necessary data for exercising a cost model to determine the cost of the first year of ownership, encompassing equipment purchase, installation, and maintenance.

The costs associated with introduction and operation of the SAB concept were assessed through the exercise of a computer-based cost model developed for FAA study DOT-FA74WA-3506. This model determines the annual and cumulative costs associated with each SAB concept and user category and tabulates these costs for a single aircraft and for the total user community.

Two types of data were provided to the economic analysis model (EAM): data unique to the particular SAB concept being evaluated, and data common to any avionic concept being evaluated. The specific requirements for each type of data were defined during this project and past studies.

1.4 REPORT ORGANIZATION

This report consists of seven chapters, describing the technical approach, data acquisition, analyses conducted, and results and conclusions obtained. The appendixes present detailed supporting data and results.

Chapter Two presents a technical description of the two concepts developed, the rationale associated with each concept, historical data on similar system development, operational scenarios and limitations, and the communities expected to benefit from each concept. This chapter also identifies the modifications that will be required at ground stations in implementing SAB. Although no attempt is made to calculate those costs, the three primary systems in the FAA inventory are reviewed and areas requiring modification or addition of functions are identified.

Chapter Three investigates the effect of introducing the SAB concept into the national airspace. Scenarios for aircraft densities, modes of operation, and limitations of participating communities are developed and evaluated. Link reliability, probability of interrogation and reply, and effect on aircraft not equipped with SAB are evaluated. Additionally, the effect of equipment modified for SAB operating in ATCRBS-only areas is investigated and evaluated.

Chapter Four presents the specific cost, reliability, and maintainability data for both the commercial and general aviation SAB concepts. Detailed avionic costs for modification kits that would be used with existing ATCRBS avionics and new ATCRBS avionics incorporating the SAB features are developed.

In Chapter Five the avionics implementation costs of each SAB concept are presented and pertinent data are developed. These data include installation costs, aircraft population statistics, and equipment configurations reflecting the practices and trends of the specific user communities that would be participants in a selective address system.

Chapter Six presents the results obtained from the economic-analysis model. Acquisition, installation, and maintenance support costs of the SAB equipments are tied to user population and summarized for individual aircraft and for the total user communities. These costs are combined to provide the cost of the first year of ownership to the individual owner and to the user community.

Chapter Seven summarizes the results of the investigation and presents specific conclusions resulting from the economic and operational evaluation of the SAB concept.

Appendix A provides detailed timing and logic designs for both the one-out-of-eight and the 4096 SABs. Appendix B develops material cost and labor hours for each module and system.

CHAPTER TWO

SYSTEM DESCRIPTION

Since the early 1960s, civil air traffic control has been enhanced by use of the secondary surveillance radar, which has provided accurate range, identity, and altitude information on equipped aircraft in the national air space (NAS). The system is commonly referred to as the Air Traffic Control Radar Beacon System or ATCRBS. The system utilizes interrogations from ground-based radars on 1030 MHz and receives replies from airborne transponders on 1090 MHz. By correlating replies with a given interrogation, range and bearing information is computed at each radar site or its remote processing center. Identity and altitude information is obtained through controlled coded interrogations referred to as Mode A and Mode C interrogations, respectively. Two other modes, B and D, are implemented in ground equipment and the majority of high performance avionics but are presently not used in air traffic control. The FAA Technical Service Order (TSO) C74b, which governs operation of the airborne ATC transponder, identifies these four available modes of interrogation and specifies the characteristics of the required replies in which twelve coded pulses and two framing pulses are used by replying aircraft. The twelve coded pulses are used to generate 2^{12} or 4096 discrete identity replies or altitude codes -- depending on the nature of the interrogation message. Synchronous garble associated with ATCRBS operation occurs when two transponder-equipped aircraft are at a slant range of 1.7 nautical miles of each other and within the beam of the interrogating radar. Although garble can occur with enroute radar systems, the ATC separation standards preclude extended continuation of the required conditions and allow adequate time for self correction without reducing flight safety or tracking capability. In the terminal radar environment, however, the situation can be severe because of aircraft maneuvering, shorter separation standards, and the presence of many transponder-equipped aircraft outside the Terminal Control Area (TCA) and not under air traffic control, but which could set up the geometry necessary for generation of synchronous garble. This chapter describes two selective address beacon systems that could minimize synchronous garble in the terminal areas and improve tracking capability of aircraft under air traffic control.

The development of a Selective Address Beacon system must have as its primary objective the provisions for selectively limiting the replies from the transponders visible to the radar system during any single sweep. Such limiting can be accomplished through discrete addressing of aircraft

interrogations using the ATC-assigned 4096 coding or through simpler techniques that discriminate between only part of the 4096 code (e.g., the last few bits in the codes). Since the purpose of SAB would be the limiting or elimination of synchronously garbled replies, the degree of sophistication required in system development must depend on the severity of the problem and where the problem occurs. Therefore, either fully discrete 4096 interrogations or more limited interrogations (in which some, but not all, aircraft are selectively interrogated) can be utilized to alleviate synchronous garbling problems.

2.1 ONE-OUT-OF-EIGHT SYSTEM

Air Traffic Control identifies controlled aircraft in the NAS by assignment of four-digit transponder codes* to each aircraft. These coded identities are normally retained throughout the entire flight of the aircraft. Only a select few of the codes are dedicated to special functions such as uncontrolled transponder-equipped aircraft (code 1200), communication failure (code 7600), or emergency (code 7700). The majority of the available codes are sequentially assigned to controlled aircraft on the basis of code availability and retained throughout the flight. Because the flight paths are random, the probability of two aircraft having the same last digit is equally random. This rationale allows the development of a simple concept of selective addressing that would elicit replies from SAB transponders whose last digit matches the coding in the interrogation and suppress all transponders (equipped with the SAB modification) whose last digit is different. Therefore, an uplink interrogation with coding 5 would generate replies from SAB aircraft with transponders set to 0105, 7345, etc., but not from those set to 0103, 0106, 7434, 7431, etc.

The SAB system envisioned would be passive, monitoring the SSR interrogations and inhibiting replies when a SAB interrogation does not match the final transponder digit. Figure 2-1 presents the logic flow diagram of the SAB decision process. Upon receipt of an interrogation, the SAB modification circuitry would decode the video signal received by the transponder and search for SAB-peculiar data. On recognition of valid data, comparator circuitry can match the transmitted data with the D_1-D_2-D_4 bits of the aircraft's assigned 4096 code. A proper match results in the system remaining in a passive mode and allowing normal transponder replies. A failure-to-match after valid data detection will cause the generation of a 25-μsec internal signal that will inhibit the modulator of the transponder from replying to the interrogation. That inhibition is the only change to the normal operation of ATCRBS.

A possible one-out-of-eight concept utilizes the standard two-pulse format of ATCRBS interrogation (i.e., the P_1 and P_3 pulses) with five

*The four digits are octal digits, formed by three bits each and resulting in 8^4 or 4096 codes.

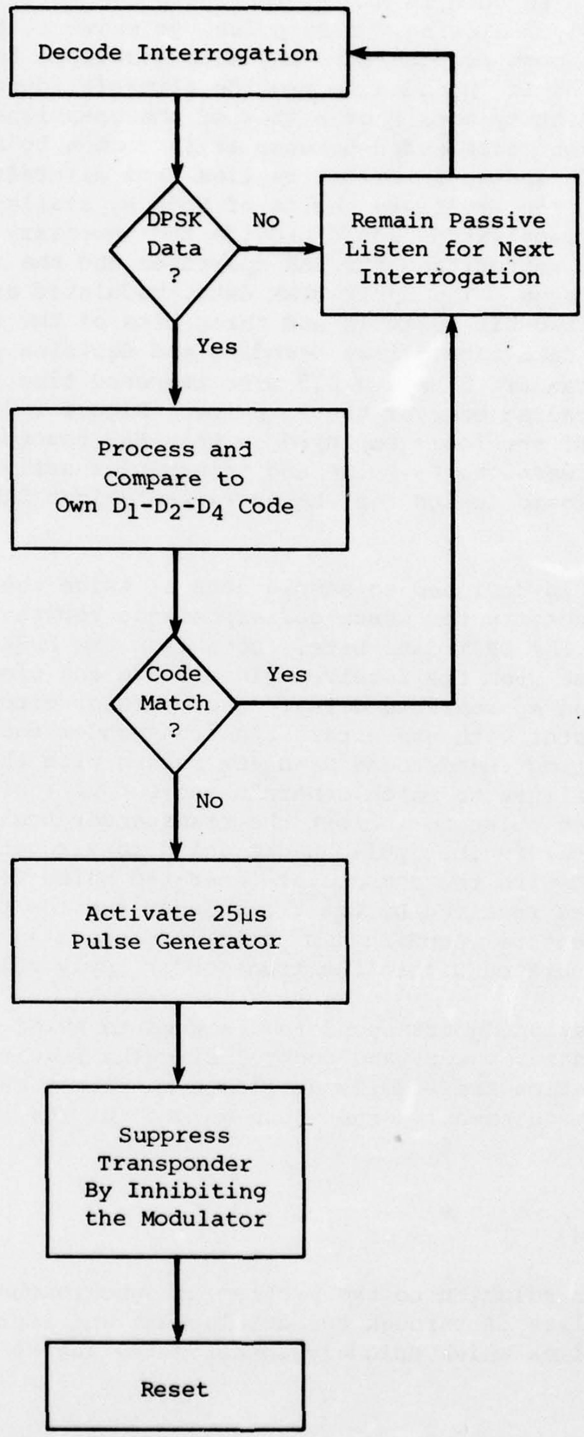

Figure 2-1. ONE-OUT-OF-EIGHT LOGIC FLOW DIAGRAM

additional pulses encoded in a differential phase shift keying (DPSK)* format immediately following the P_3 pulse, as shown in the upper portion of Figure 2-2. Although adaptable to any mode available to ground interrogations, the concept is intended to provide aircraft identity and therefore could use the identity mode A or either of the unassigned modes (Mode B or D). Mode A is not recommended because it is common to all transponder-equipped aircraft and would elicit replies from aircraft not modified for SAB operations. The arbitrary choice of Mode B, available in most transponders but not activated, would provide the necessary discrimination between aircraft retrofitted for SAB operation and the remainder of the aircraft in the area. The 5-bit DPSK data, modulated at a 4-mbps rate, would include a two-bit preamble and three bits of the D_1-D_2-D_4 identity code. The high data rate allows decoding and decision processing without affecting the standard 3 μsec ± 0.5 μsec response time from a transponder following the leading edge of the P_3 pulse. Figure 2-2 is a simplified timing diagram of the logic employed in this SAB concept and shows the relationship between the P_3 pulse and transponder activity. Detailed timing and the logic design for the one-out-of-eight SAB are shown in Appendix A.

The system is designed to sample data at twice the DPSK data rate to preclude the necessity for phase correspondence between the SAB clock and the position of the DPSK data bits. Data from the DPSK is time correlated with the P_1 pulse from the received video stage and clocked into a shift register after an appropriate delay. A comparator circuit matches the output of the register with the aircraft's transponder code setting (last digit) by comparing the decoded D_1-D_2-D_4 pulses with the corresponding aircraft codes. Failure to match generates an output logic state that will trigger a 25-μsec pulse to inhibit the transponder transmitter. Two control circuits, receiver inhibit pulse and a valid interrogation pulse, are employed and gated with the comparator-generated pulse to ensure that a valid interrogation was received by the transponder and the transponder is ready to reply. The entire decoding and decision process is completed and an inhibit signal generated within the transponder reply delay time of 3 ± 0.5 μsec.

Review of existing transponders designed to ARINC characteristic 572 shows that all data, power, and control circuits required for operation of the SAB modification are readily available at either the main or ATE (automatic test equipment) connections mounted at the rear of the transponder.

2.2 4096 SYSTEM

The optimum solution to the problem of synchronous garbling of transponder replies is through the development and implementation of a communications link which uniquely interrogates and solicits replies from

*The concept of DPSK modulation at a 4-mbps rate has been developed and thoroughly tested by Lincoln Laboratory in the development of the DABS concept.

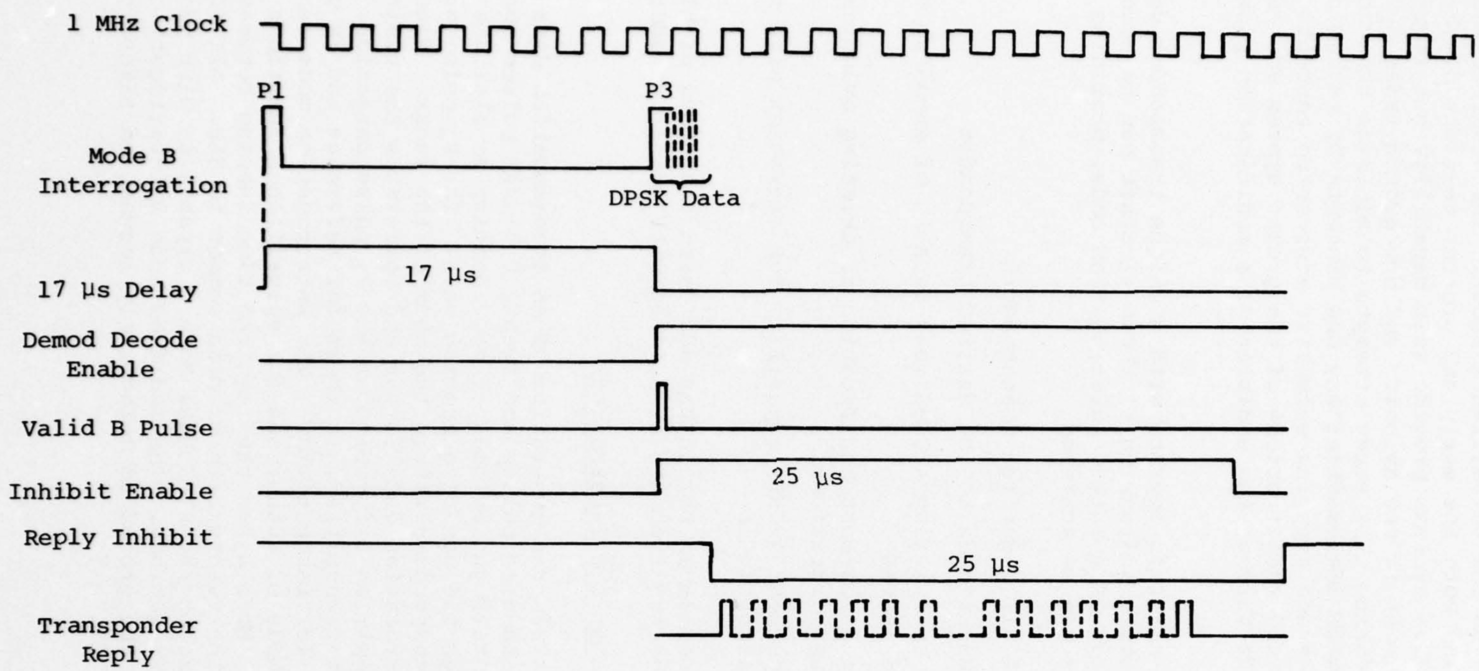

Figure 2-2. ONE-OUT-OF-EIGHT SAB SIMPLIFIED TIMING CONTROL

every aircraft visible to the surveillance radar. The discrete address beacon system (DABS) and both the early and present versions of the British address selective (ADSEL) systems provide this capability but require the development and deployment of new avionics and new ground radar systems. The system developed during this study attempts to minimize the capital expenditure associated with implementing any new concepts by reviewing the existing ATCRBS designs and adapting selective addressing concepts that will operate with limited modifications of the ground system and can be implemented in aircraft through the addition of a modification package to existing avionics.

Since controlled aircraft operate with a unique transponder code assigned by ATC, selective addressing of these aircraft can be accomplished through the transmission of a unique interrogation code, providing the following capabilities can be achieved:

- Suppression of all undesired transponders
- Reliable communications to the desired transponder
- Adaptation of an existing ATCRBS mode capable of encoding the selective data stream
- Development of a low-cost modification to existing avionics that will support SAB operations
- Retention of present ATCRBS capability for operation with non-SAB-equipped aircraft

The 4096 system described herein has addressed the above problems and is designed to meet the requirements associated with selective addressing.

2.2.1 Characteristics of the Interrogator

The 4096 SAB requires the generation of an interrogation data stream containing the P_1-P_2 standard pulses and twenty 0.5-μsec pulses containing the unique address, interrogation mode (i.e., identity or altitude), and error detection through the use of a Hamming code. The P_2 pulse provides suppression of all transponders within the beam of the radar. Figure 2-3 presents the SAB interrogation data format and correlates the timing of the SAB transponder reply as a function of the P_1 pulse detection. The P_3 pulse, although not transmitted, is shown for reference and is used by the ground processors for range timing. The interrogation mode required for SAB operation is Mode D, authorized for surveillance functions but presently unassigned. Mode D has the required time spacing between P_1 and P_3 pulses to include the twenty bits of data common to SAB. All FAA surveillance radars except the BI-3 have Mode D capability with provisions for interlace of interrogations. The modified Mode D interrogation shown in Figure 2-3 permits the ground to selectively request an aircraft identity or altitude reply.

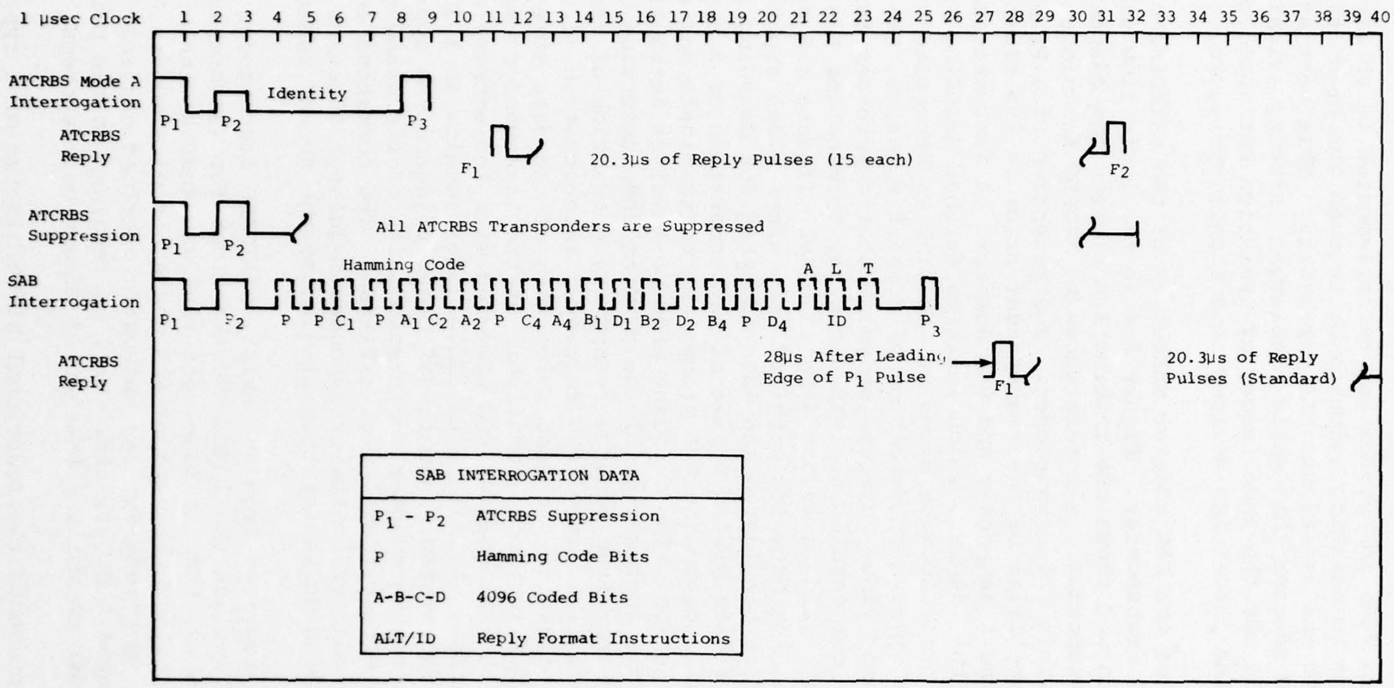

Figure 2-3. 4096 SAB INTERROGATION AND REPLY FORMAT

2.2.2 Characteristics of Avionics Modification

The proposed 4096 SAB system can be implemented in an aircraft either as a modification to existing avionics or through the production of new transponders with the additional SAB capability. This section presents the details of a SAB adapter that would complement existing avionics. A new transponder would use the same theory of operation but would contain all the ATCRBS and SAB processing devices in a single enclosure.

The design of the SAB adapter makes use of the existing circuitry in the basic ATCRBS transponder. Figure 2-4 is the logic flow diagram of the adapter operation and shows the interaction between the adapter and the basic ATCRBS transponder. All references to ATCRBS functions refer to the operation within the transponder. The reception of a P_1 pulse available at the IF amplifier of the transponder prior to the video switch activates both the transponder and the adapter. A four-microsecond delay is triggered in the adapter, which inhibits further decoding in the adapter. The transponder proceeds with decoding, seeking P_2 detection through the ditch digger circuitry. On detection of a valid P_2 pulse, the transponder generates a 32-μsec video suppression pulse that suppresses further transponder activity but enables the SAB decoding, terminating the initial lockout delay and initiating a second 4-μsec delay. If data are present before 4 μsec (data could be detected within 2 μsec after video suppression), the delay timing is terminated and data accepted for decoding and comparison. Absence of data within 4 μsec of the generation of a video suppression pulse will cause the SAB processing to terminate and reset for the next interrogation. The decoding process involves extraction of all twenty data pulses, application of the Hamming Code detection and correction logic to ensure error-free message reception, extraction of the 12-bit 4096 address, and identification of the requested interrogation (i.e., identity or altitude) contained in the last three bits of the data stream. The aircraft's assigned 4096 code, available at the transponder rear connector, is processed in the SAB adapter and compared with the address contained in the interrogation. A failure to match codes results in a 30-μsec suppression of the SAB system. A match of codes triggers the appropriate encoding network in the adapter for transmission of the standard ATCRBS format reply for either identity or altitude. The formatted encoded reply is sent from the adapter to the transponder modulator together with a transmitter-enabling pulse for transmission to the ground radar.

The outputs required from the existing ATCRBS transponder not previously identified include the 1 MHz/690 kHz clock for synchronizing action between the two sets, the altitude code, and an external inhibit control -- all available at either the main or ATE connector of a modern ARINC transponder. Common functions such as automatic overload control (AOC), low sensitivity, antenna monitor, etc., will be retained in the primary ATCRBS unit with shut-down capability that would affect both systems.

Figure 2-5 presents the functional block diagram of a typical ATCRBS transponder and the SAB adapter. Circuitry peculiar to the SAB design (e.g., decoding logic) is detailed and included in Appendix A to this

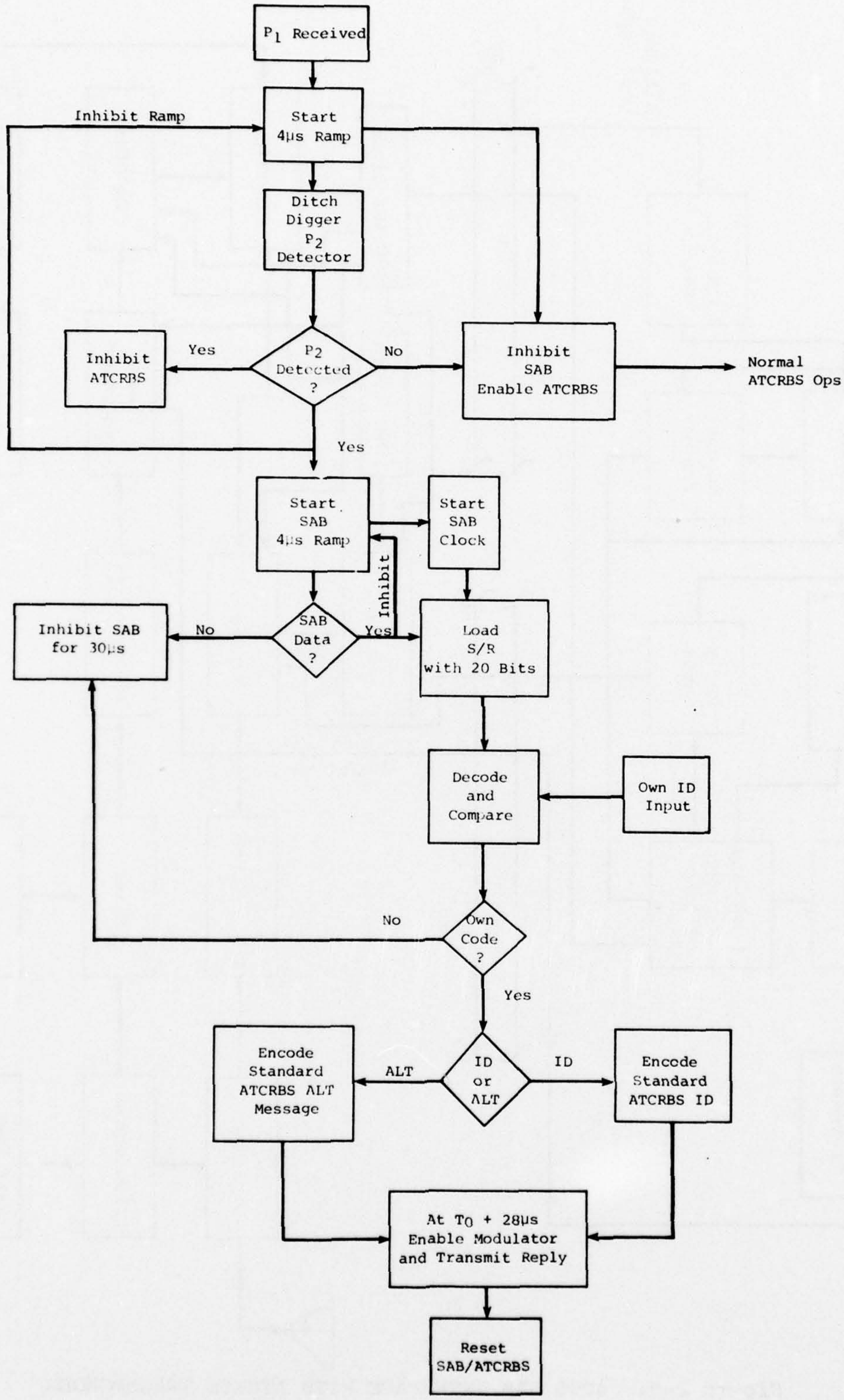

Figure 2-4. **4096 SAB LOGIC FLOW DIAGRAM**

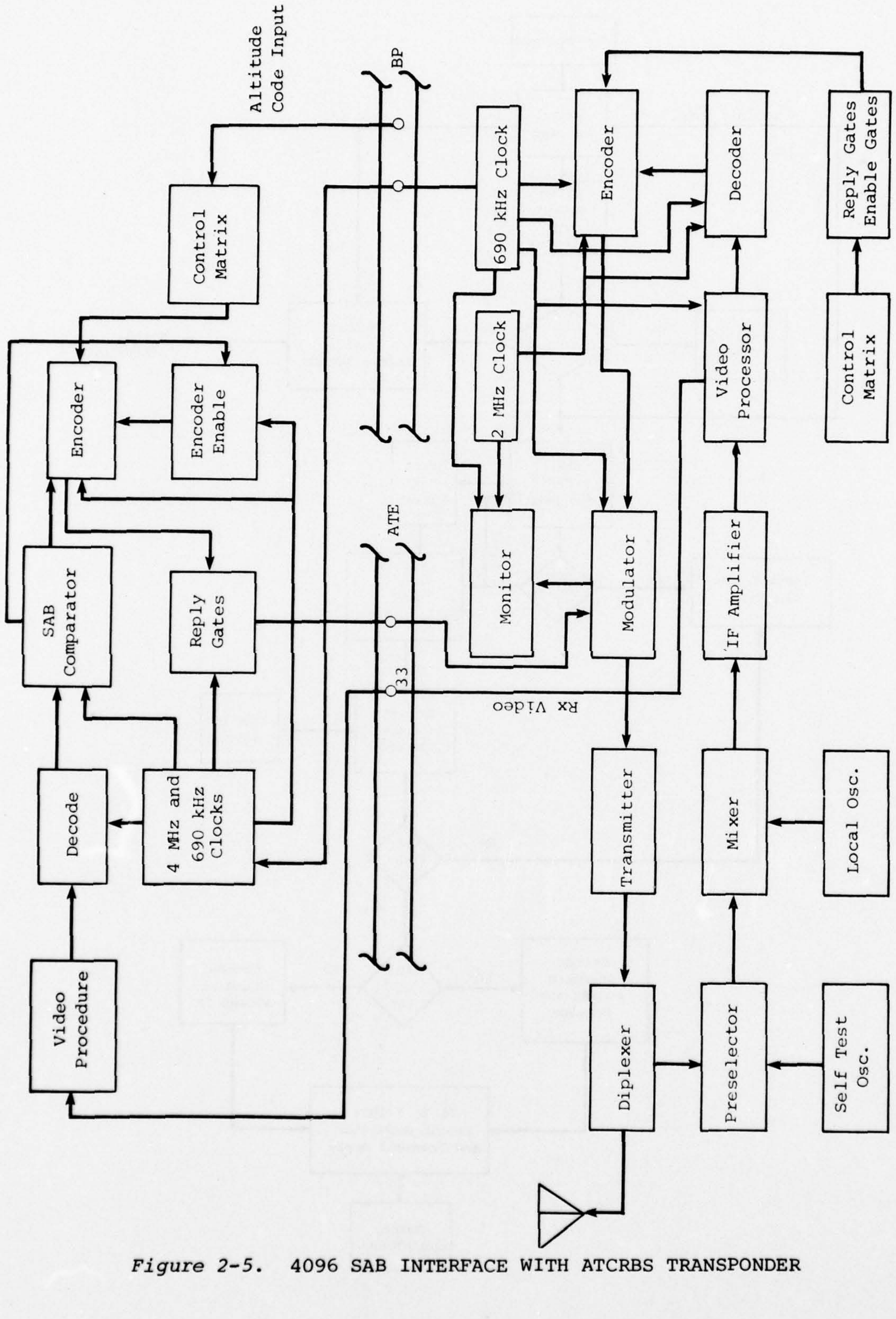

Figure 2-5. 4096 SAB INTERFACE WITH ATCRBS TRANSPONDER

report. Common functions such as video processors or encoders are normally provided in manuals on existing transponders and are not included in this report.

The 4096 SAB adapter concept is adaptable to high-performance aircraft using ARINC-type avionics because of the availability of critical circuit test points and functions at the output connectors and the Mode D capability. However, the avionics installed in low-performance general aviation aircraft are not suitable for the addition of external adapters and new transponders would have to be developed with a combined ATCRBS/SAB capability.

2.3 GROUND SYSTEM MODIFICATIONS

The introduction of either SAB concept will require certain modifications to the ground interrogator systems of the secondary surveillance radar. The required equipment modifications and additions are identified in this report but no attempt is made to provide either the design detail or cost estimates of the modifications, as these are beyond the scope of the study. Although three types of systems are deployed (the BI-3, -4, and -5 interrogators), generic modifications of typical systems are identified.

2.3.1 One-Out-of-Eight SAB Concept Ground Modifications

The one-out-of-eight concept requires interrogation transmission in the B mode (15-microsecond pulse spacing). All active FAA radars have this feature available as a front panel selection. The interlace of modes A, B, and C is panel-selected but requires modification to generate the specific sequence advocated in Chapter Three.

The transmitter modulator must be modified to generate differential-phase-shift-keying (DPSK) data modulation when operating in the B mode. The techniques for DPSK modulation have been developed for DABS. Adaptation of the technology to the 5-bit SAB data at a 4-mbps rate should be relatively simple.

The receive portion of the system is unaffected since all replies from airborne transponders remain unchanged. However, the programs supporting ATCRBS computer operations must include recognition of the Mode B operation for aircraft identity and range determination.

2.3.2 4096 SAB Concept Ground Modifications

The 4096 SAB concept requires several modifications to the transmitter portion of the ground interrogator. The receiver system remains unchanged since all transponder replies are in the same format as presently used in ATCRBS operation. Software changes in data processing are required to permit the system to recognize the Mode D operation used by the 4096 SAB.

2.3.2.1 Mode Selection

The concept requires activation of Mode D capability already available on modern interrogators. Although front panel controls provide Mode D interlace provisions, the specific interlace advocated in Chapter Three or required at field locations on the basis of traffic density and synchronous garble severity requires a programmed card or interlace pattern control modification to the control system.

2.3.2.2 Side Lobe Suppression (SLS)

The side lobe suppression pulse (P_2) presently switched to the omniantenna of a radar system must be included in the main beam of the antenna when interrogating in the D mode. This modification can be accomplished by replacing the pulse switching network with a controlled divider switching network.

2.3.2.3 Transmitter Modulator

The modulator of the system will require either modification or replacement to handle the narrower pulse data peculiar to the 4096 SAB. In addition, the duty cycle of the exciter modulator and the transmitter will be increased because of the data stream necessary for selective interrogations.

2.3.2.4 Power Supplies

The transmitter power supplies will require modification or replacement to provide the necessary transmitter duty cycle associated with the additional data pulses of SAB interrogations without excessive droop of the signal.

2.3.2.5 Data Processing

The 4096 SAB concept requires the addition of a minicomputer capable of storing aircraft identification and bearing information, updating the information in real time, scheduling SAB interrogations as a function of identity and position, and generating the proper data stream for exciter modulation. The data processor would be located at the radar site and would not require interface or data exchange with the automated radar terminal service (ARTS) processors.

CHAPTER THREE

SAB OPERABILITY EVALUATION

The SAB concepts identified in this study were developed to meet the need for either reducing or eliminating the synchronous garble phenomenon at minimum cost to both the aviation communities and the surveillance networks. The one-out-of-eight concept makes maximum use of existing ATCRBS transponder characteristics and can be implemented as a low-cost modification to high-performance avionics. The 4096 SAB concept requires more sophisticated modifications or new avionics but is capable of eliminating synchronous garble in all airspace in which it is implemented.

This chapter identifies the implementation strategy required for each concept, evaluates the operational capability of each concept, and analyzes the communications reliability expected in terminal areas for each concept.

3.1 ONE-OUT-OF-EIGHT SAB

The one-out-of-eight SAB is intended to provide a degree of improvement in aircraft identification for a community of users under positive air traffic control. The majority of aircraft in this category are the commercial air carriers, which normally use ARINC-characteristic avionics. In addition, while under positive air traffic control, these aircraft have unique identification codes assigned for tracking by the ATC system. Modern ATCRBS transponders meeting ARINC specifications are designed to operate in all four interrogation modes authorized for U.S. airspace (Modes A, B, C, and D), although only the identity (Mode A) and altitude (Mode C) modes are utilized by the ATC system.

The operation of a one-out-of-eight system depends on the ability of an interrogator to selectively address aircraft in the beam of the radar by requesting replies from aircraft with the last digit of the assigned code matching the code in the interrogation. The equipment described in Chapter Two provides this capability by suppressing transponder replies when data are detected that do not match the transponder's own code. However, many aircraft not under positive control and not expected to be equipped with the SAB capability are visible to the radar beam during interrogations. These aircraft must be excluded from the interrogation and have their transponders suppressed. One convenient and available

method is the use of the Mode B capability of the ATCRBS system. Present transponders will not reply to the Mode B interrogation unless they are enabled to respond by physical strapping of control functions within the transponder. Transmission of Mode B interrogations, together with the data stream following the P_3 pulse, would ensure that only SAB-equipped aircraft would respond.

This section evaluates the effectiveness of the SAB concept in reducing synchronous garble in the terminal environment by evaluating the probability of multiple aircraft having the same last digit, the probability that two aircraft with the same code are in a garble cell, and the capacity of the SAB concept as a function of interrogation interlace and pulse repetition frequency.

3.1.1 Probability of Aircraft With Same Code

Assuming the aircraft population of interest consists of only one-out-of-eight system participants with unique 4096 codes, use of only the last digit of the code gives a maximum of eight selective addresses. This study does not consider the "0" digit as a possible code since the digital equivalent contains no detectable data. Therefore, the available selective codes are the digits 1 through 7.

The classical "Birthday Problem" approach can be applied to determine the probability that two or more aircraft in a population visible to a radar beam have the same last digit when the code assignments are randomly chosen. The probability is expressed by

$$P = 1 - \frac{A!}{(A - N)! \times (A)^n}$$

where

A = number of available codes

N = number of aircraft visible

Figure 3-1 presents the probability as a function of the number of aircraft up to a total of eight. Any number of aircraft above eight will have a 100-percent probability of duplication.

3.1.2 Probability of Aircraft In a Garble Cell

The generation of synchronous garble is a function of the geometric relationship between aircraft. A garble cell can be defined as a sphere with a diameter of approximately 1.7 nautical miles. Any two or more aircraft within this cell and simultaneously visible to the interrogator radar will generate replies that will overlap at the ground receiver. Since the possible number of garble cells in a 60-nautical-mile radar coverage is very large, it is extremely difficult to predict the probability of synchronous garbling. Each radar site has data identifying the

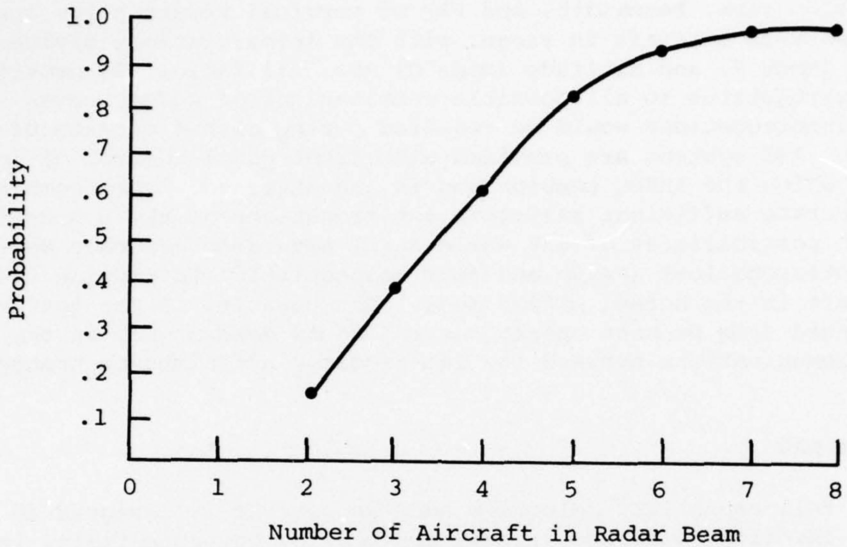

Figure 3-1. PROBABILITY OF TWO OR MORE AIRCRAFT WITH SAME CODE - ONE-OUT-OF-EIGHT SAB CONCEPT

severity of synchronous garble experienced at that location. Making the practical assumption that synchronous garble is generated by two, and only two, aircraft, the one-out-of-eight SAB concept will have a sevenfold improvement in reducing the problem. That is to say, the probability that the two aircraft in the garble cell have the same last digit in their code is less than 15 percent (refer to Figure 3-1).

3.1.3 System Capacity

The existing ground interrogators operating in terminal environments exhibit the following characteristics:

Rotation Rate	15 revolutions per minute
Beam Width	4 degrees nominal
Pulse Repetition Frequency (PRF)	400 interrogations per second (nominal)
Range	60 nautical miles
Mode Interlace	AAC

The PRF is a function of the pulse repetition rate of the primary radar associated with each airport surveillance radar (ASR). However, secondary surveillance radar systems have the ability to vary the PRF between 150 and 450 interrogations per second. To cause the minimum impact on existing

operations, the 400-PRF rate has been used in determining a usable interlace that could be adapted in support of both ATCRBS and SAB operations. The rotation rate, beamwidth, and PRF of terminal radars allow approximately 18 hits on each aircraft in range, with the interrogations divided between identity (Mode A) and altitude (Mode C) at a 2:1 ratio. To provide selective interrogations to all possible combinations of codes, seven selective address interrogations would be required during each 4 degrees of radar rotation. ASR systems are provided with front panel control of interlace mixes of which the AABBC combination is one standard. This combination would generate sufficient selective interrogations in the B mode to cover the seven possibilities of SAB while still retaining adequate Mode A and Mode C interrogations (seven and four respectively) to provide tracking of aircraft in the normal ATCRBS mode. The capacity of the system would be unchanged from present operations and would depend only on the reliability of communications between the interrogator and airborne transponders.

3.2 4096 SAB

The full-capability selective address concept is designed to provide aircraft identity, altitude, range, and bearing by sequentially interrogating every aircraft with a unique transponder code in range of a ground interrogator. The necessity for maintaining surveillance of non-SAB equipped aircraft is satisfied through routine ATCRBS modes of ASR equipment. The selective mode of the system requires that all participants in the beam of the radar, except the selected transponder, suppress replies during a SAB interrogation. This is accomplished by switching the P_2 suppression pulse with the main beam of a radar, while still maintaining side lobe suppression (SLS) characteristics during the selective interrogation. The data contained in the interrogation will be detected by all SAB-equipped aircraft and decoded for comparison to its own code. A standard ATCRBS reply will be generated only by the transponder that has matched the interrogation coded data. The mode necessary for operation of the SAB must be either the available Mode D or a new mode with pulse spacing and range timing characteristics that permit transmission of twenty half-microsecond pulses spaced at one microsecond intervals following the P_2 pulse of the interrogator. This study assumes that the D mode is available and would be used since its use would minimize the timing modifications in the ground receiver systems.

This section evaluates the use of the 4096 SAB concept in the terminal environment and analyzes the operational capacity of the concept as a function of aircraft density.

3.2.1 Probability of Aircraft with Same Code

The assignment of unique codes to aircraft under ATC control is carefully controlled to ensure that the same code is not assigned to two aircraft that may appear in the controlled airspace. Therefore, the probability that two aircraft visible to a SAB radar system have the same code is zero. However, even if the code assignment procedure was totally random, the probability of two or more aircraft having the same code would

be very low. This probability is a function of the number of available codes and the number of aircraft in sight of the radar system and can be determined by application of the equation presented in Section 3.1.1 of Chapter Three. Figure 3-2 shows the results for varying numbers of aircraft in a terminal environment. Although the probability of two or more aircraft having the same code in a population of 50 SAB-equipped aircraft is 26 percent, the probability that two or more aircraft visible to a scanning beam of 4 degrees with up to 15 SAB-equipped aircraft is only 2.5 percent. As in the case of the one-out-of-eight concept, the probability of two aircraft having the same code and being in a garble cell is not easily determined. However, even presuming random code assignment, the expected reduction of synchronous garble by application of the 4096 SAB concept can be determined by review of ASR data for specific sites and applying the computed probability from the figure for the population of aircraft in the beam of the ASR.

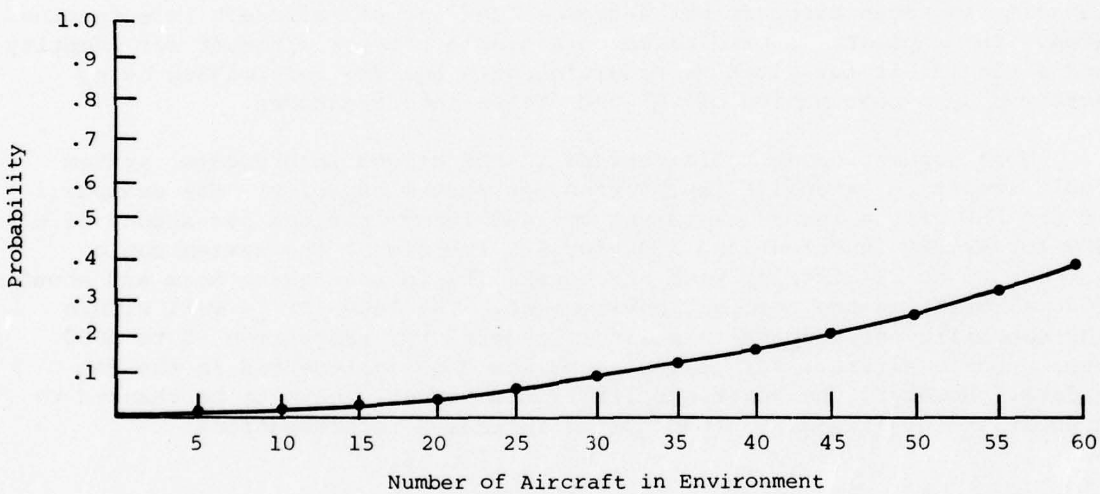

Figure 3-2. PROBABILITY OF TWO OR MORE AIRCRAFT WITH SAME CODE - 4096 SAB CONCEPT

3.2.2 System Capacity

Introducing the SAB concept to a terminal environment will require retaining the present ATCRBS capability with the addition of selective interrogations to aircraft within the 60-nautical-mile range of radar

coverage. The existing terminal radars exhibit the following characteristics:

Rotation Rate	15 revolutions per minute
Pulse Repetition Frequency	150 to 450 interrogations per second (400 nominal)
Beam Width	4 degrees
Range	60 nautical miles
Mode Interlace	AAC

If only the mode interlace was changed to $AAS_1S_2CS_1S_2$, where the S_1 (identity) and S_2 (altitude) modes of SAB used the existing D-mode timing, the system could support five SAB-equipped aircraft in a 4-degree radar scan or a total of 457 SAB-equipped aircraft uniformly distributed in the terminal area. Two minor modifications to present operations, decreasing the rotation rate to 12 rpm and increasing the PRF to the maximum available limit of 450 interrogations per second, would increase system capacity to seven aircraft per 4-degree scan and 643 aircraft in a terminal area. The capacity is predicated on a single hit per aircraft for identity and a single hit for altitude reporting, with bearing information being measured by a combination of SAB and ATCRBS interrogations.

More sophisticated modifications to the ground interrogator system could result in extensive improvements in system capacity. For example, if the PRF of the radar was raised to 1400 interrogations per second (i.e., 400 for ATCRBS functions and 1000 for SAB functions) the system could support up to 22 aircraft with SAB capability in a 4-degree beam and about 2000 aircraft in the terminal environment. The 1400 PRF is well within the capability of comparable military radars (PRF range from 15 to 3000 pps) used in aircraft surveillance and could be implemented in the FAA radars. However, the power supplies would probably have to be changed to support the additional RF load due to increased interrogations.

3.3 OVERVIEW OF COMMUNICATIONS RELIABILITY

Successful communications between the ground interrogator and an airborne transponder in the beam of the radar depend on two key factors: the availability of the transponder to reply to an interrogation, and the receipt and decoding of a clear reply by the interrogator receiver. In an environment with only one active ground interrogator, selective addressing would give a very high probability of successful communications. However, most airspace of interest is blanketed by overlapping radars, each one affecting the availability of a transponder to reply to an interrogation. Two factors affect transponder availability: internal suppression caused by the transponder replying to a valid interrogation, and external suppression caused by the SLS pulse of a nearby radar when the transponder is illuminated by the interrogator antenna sidelobe. In each case, the suppression period is approximately 35 μsec long plus the

duration of the interrogation period (i.e., 2 μsec for SLS, 8 μsec for Mode A, and 21 μsec for Mode C). The probability of having a transponder available to reply to any interrogation is a function of the length of the suppression period, total time available for one revolution of a radar, and the number of radars illuminating the transponder. Since radars are not synchronized either in rotation or PRF, the effect can be estimated as a probability of coincidence of the suppression period occurring during the desired interrogation time frame, and, assuming a radar PRF of 400, is expressed by the following probability-of-success expression:

$$P_{success} \approx \left\{ 1 - PRF \left[\frac{\delta}{360} t_c + \left(1 - \frac{\delta}{360} \right) t_s \right] \right\}^{N-1}$$

where

t_c = suppression due to replies to another radar ($56 \cdot 10^{-6}$ seconds)

t_s = suppression due to SLS interrogation ($37 \cdot 10^{-6}$ seconds)

N = number of radars illuminating transponder

PRF = pulse repetition frequency (400 interrogations per second)

δ = nominal radar main beam width (4 degrees)

The expression assumes that interrogations from each radar are independent. Since PRFs and rotation rates of adjacent radar sites are intentionally desynchronized, this assumption is partially justified. There is a small probability, however, that a secondary radar interrogation will arrive during a period when the transponder is already suppressed. Such an interrogation would cause no interference. The expression considers a worst case: that all radars visible to the transponder for valid interrogations always cause side lobe suppression. Such interference is highly dependent on the geometry of sites and range to the transponder as well as the state of the transponder when an interrogation is received. For the limited number of radars and suppression times used in this analysis, the expression should be very accurate. Even assuming worst case conditions, estimated availability of the transponder is very high (99.9 percent for 5 radars).

The probability of successfully receiving a reply by the interrogator receiver can also be treated as a time coincidence problem, since the reply can be garbled by fruit generated by transponders replying to other interrogators. The factors contributing to fruit generation are the number of aircraft in the environment, number of radars soliciting replies, the reply rate per aircraft per radar revolution, and the duration of a coded reply. The probability of successfully receiving a desired reply is one minus the probability of time coincidence of overlapping replies, and can be expressed by the following:

$$P_{success} = \left(1 - \frac{N_{AC} \times R \times PW}{T} \right)^{N_R - 1}$$

where

N_{AC} = number of aircraft in area

N_R = number of radar interrogators

R = reply rate per aircraft per revolution

PW = width of reply pulses (20.3 μsec)

T = time for one revolution of radar in microseconds

The probability of successful communications to a given aircraft operating in the SAB mode, on the basis of one interrogation per revolution of a radar, is dependent on the factors discussed and controlled by the number of interrogators and aircraft in the environment. Figure 3-3

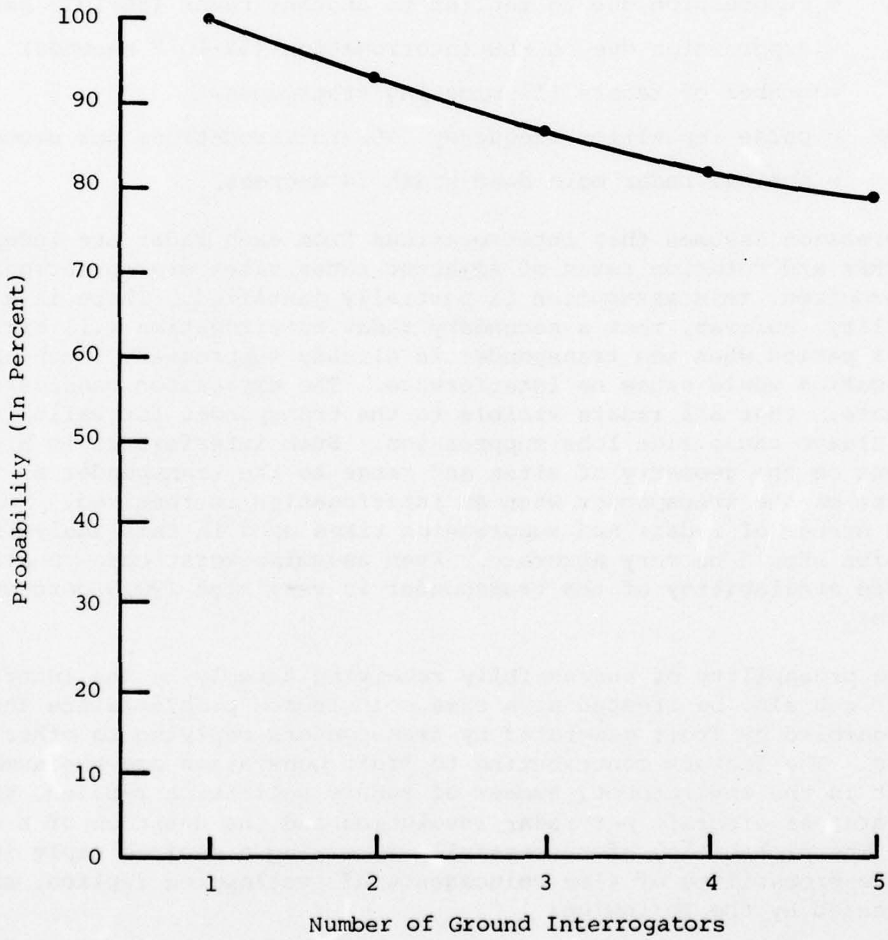

Figure 3-3. PROBABILITY OF SUCCESSFUL COMMUNICATIONS IN AN ENVIRONMENT WITH 643 AIRCRAFT

presents a worst-case probability of success as a function of the number of radars for the maximum traffic density that a SAB interrogator can handle (i.e., 643 aircraft) without major modifications to existing systems. Even under worst-case conditions the resultant probability of reliable communications is sufficiently high, based on single interrogations, for reducing or eliminating synchronous garble in the system.

Further, if the aircraft is not in a garbling position (relative to other aircraft), its replies to the normal Mode A and C interrogations will come through, thereby further improving the effectiveness of the overall SAB surveillance concept.

CHAPTER FOUR

AVIONICS COST DEVELOPMENT

The equipment cost data developed in this chapter provide the basis for a cost analysis of the one-out-of-eight and the 4096 SAB systems. Careful development of these data was an essential step in the overall evaluation of a cost-effective selective addressing system.

To provide accurate data on avionics costs, it was necessary to develop detailed equipment designs based on the probable production versions of similar avionics currently available from air carrier and general aviation manufacturers. The expected quantities of production affect the cost of any avionics equipment. The total annual production quantity for a single manufacturer was presumed to be 1000 units to permit a reasonable production-line capability and a reasonable discount in parts and material procurement. The costs developed in this chapter are calculated in 1975 dollars to permit comparison with the costs previously reported by ARINC Research for other upgraded third-generation ATC systems. Advanced technology will not be required to meet any of the concepts defined in this study.

4.1 ONE-OUT-OF-EIGHT SAB

Equipment costs for this concept were developed only for avionics suitable for high-performance aircraft using ARINC-characteristic equipment. The majority of aircraft operating with unique transponder codes (and therefore candidates for a limited SAB system) are the air carriers and high-performance general aviation aircraft. Users of low-performance aircraft avionics often operate in VFR conditions and transmit a uniform code (1200) transponder, and are therefore not suitable for the SAB concept of selective addressing. Moreover, the one-out-of-eight concept would require added capabilities to be redesigned into general aviation quality transponders (e.g., inclusion of Mode B) and would therefore probably be an impractical interim solution for general aviation. (It would be better to go all the way to a 4096 scheme if general aviation is to be included in a SAB system.)

Costs have been estimated for two versions of the one-out-of-eight concept: the avionics package as a modification to existing transponders, and new avionics incorporating both the ATCRBS and SAB modes of surveillance. However, conceptual design of the SAB capability is the same for

both versions of equipment. The logic required for data decoding and transponder inhibiting is presented in Figure A-2 of Appendix A. An additional module required for system operation would include the DPSK demodulator, TTL compatibility interface, and power supply regulators supporting the SAB logic. The packaging of both a SAB adapter to be used with existing transponders and a separate transponder with both SAB and ATCRBS capability is described in the following sections.

4.1.1 Adapter to be Used With Existing Avionics

The equipment required in support of this SAB concept consists of two modules or printed circuit cards containing the electronics to process, decode, and evaluate the interrogator data and generate the control signals for inhibiting the ATCRBS transponder. The modules are housed in a 1/4-ATR dwarf enclosure designed to ARINC characteristics for air transport equipment cases. Table 4-1 presents the costs of material, labor, burden, inspection, and production engineering for developing the SAB package -- the direct cost of manufacturing the modules and system. The direct cost of manufacture is identified in the table as the factory cost. A 20-percent general and administrative cost and a 15-percent profit were added to the factory cost to establish the estimated minimum selling price. This selling price would be the acquisition cost for a commercial air carrier or an avionics distributor who resells these systems to the small percentage of general-aviation users requiring high-performance avionics. The cost to these users is identified in the tables by both module and system list price.

The development of material cost and labor hours for each module and system is documented in Appendix B to this report.

4.1.2 New Avionics

A modern ATCRBS transponder developed to meet ARINC Characteristic 572 is a densely packaged electronic unit housed in a 3/8-ATR short enclosure. System functions such as the IF amplifier, decoder, and encoder are modularized for efficient maintenance. Removal and replacement of the modules with similar function modules is possible without altering the structural configuration of the transponder. The addition of the one-out-of-eight SAB function to a modern transponder would affect the design of the IF amplifier (addition of a DPSK demodulator) and the decoder-encoder modules for signal processing, timing generation, and transmitter-inhibit pulse generation. TTL compatibility, power supplies, and transponder code data are normally features of a modern transponder and will not require additional modifications. Review of a modern transponder has shown that the electronics required to support SAB operation can be added by modifying three of the existing modules (the IF amplifier, encoder, and decoder) and using a careful redesign of the cards without changing the physical parameters of these cards. Table 4-2 presents the cost development of the SAB transponder operating in both present ATCRBS and one-out-of-eight SAB concepts. The modules presented represent the configuration of a typical

Table 4-1. COST DEVELOPMENT, ONE-OUT-OF-EIGHT SAB ADAPTER, HIGH PERFORMANCE AIRCRAFT (IN DOLLARS)				
Module / Cost Category	Demodulator Card	Logic Decoder and Processor	Chassis and Test	Total
Material Cost	26.21	75.60	49.53	151.34
Material Handling @ 25% Material Cost	6.55	18.90	12.38	37.83
Labor @ $11.00/Hour	13.38	12.66	31.63	57.67
Burden @ 135% Labor	18.06	17.09	42.69	77.84
Inspection @ 5% Labor Burden	1.57	1.49	3.72	6.78
Subtotal	65.77	125.74	139.95	331.46
Engineering and Q.C. @ 25%	16.44	31.44	34.99	82.87
Factory Cost	82.21	157.18	174.94	414.33
General and Administrative @ 20%	16.44	31.44	34.99	82.87
Total Direct Cost	96.95	188.62	209.93	497.20
Profit @ 15%	14.80	28.29	31.49	74.58
Selling Price	111.75	216.91	241.42	571.78
Distribution @ 30%	33.53	65.07	72.43	171.03
List Price	145.28	281.98	313.85	742.81

transponder with all but three modules existing in manufacturers' inventory. The three exceptions are those previously identified as redesigns to accommodate SAB. The cost development is based on material and labor estimates for each module and system using the same methodology as described in Section 4.1.1. The material and labor estimates supporting the cost development are presented in Appendix B to this report.

Table 4-2. COST DEVELOPMENT, ONE-OUT-OF-EIGHT SAB TRANSPONDER, HIGH-PERFORMANCE AIRCRAFT (IN DOLLARS)

Cost Category \ Module	Transmitter	Receiver	IF Amplifier	Video Processor	Control Matrix	Monitor	Power Supply	Logic Decoder	Logic Encoder	Chassis	Final Assembly and Test	Totals
Material Cost	265.70	229.93	55.95	93.70	73.02	86.76	54.24	97.22	96.80	98.00	-	1151.32
Material Handling @ 25% Material Cost	66.43	57.48	13.99	23.43	18.26	21.69	13.56	24.31	24.20	24.50	-	287.85
Labor @ $11.00/Hour	28.73	54.30	21.30	41.10	60.92	32.12	22.47	18.33	17.51	52.13	41.53	390.44
Burden @ 135% Labor	38.79	73.30	28.76	55.48	82.24	43.36	30.34	24.74	23.64	70.37	56.06	527.08
Inspection @ 5% Labor/Burden	3.38	6.38	2.50	4.83	7.16	3.77	2.64	2.15	2.06	6.13	4.88	45.88
Subtotal	403.03	421.39	122.50	218.54	241.60	187.70	123.25	166.75	164.21	251.13	102.47	2402.57
Engineering and Q.C. @ 25%	100.76	105.35	30.63	54.64	60.40	46.93	30.81	41.69	41.05	62.78	25.62	600.66
Factory Cost	503.79	526.74	153.13	273.18	302.00	234.63	154.06	208.44	205.26	313.91	128.09	3003.23
General and Administrative @ 20%	100.76	105.35	30.63	54.64	60.40	46.93	30.81	41.69	41.05	62.78	25.62	600.66
Total Direct Cost	604.55	632.09	183.76	327.82	362.40	281.56	184.87	250.13	246.31	376.69	153.71	3603.89
Profit @ 15%	90.68	94.81	27.56	49.17	54.36	42.24	27.73	37.52	36.95	56.50	23.06	540.58
Selling Price	695.23	726.90	211.32	376.99	416.76	323.80	212.60	287.65	283.26	433.20	176.76	4144.47
Distribution @ 30%	208.57	218.07	63.40	113.10	125.03	97.14	63.78	86.29	84.98	129.96	53.03	1243.35
List Price	903.80	944.97	274.72	490.09	541.79	420.94	276.38	373.94	368.24	563.16	229.79	5387.82

4.2 4096 SAB SYSTEM

The development of equipment costs for this concept considers the probability that only high-performance aircraft would retrofit existing ATCRBS systems with SAB adapters because of the need for selective addressing of controlled aircraft. The general aviation community would most likely acquire the SAB capability through normal attrition and replacement of existing transponders with SAB transponders and the acquisition of SAB-compatible avionics for all new aircraft. Therefore, the avionics cost development considers SAB adapters for the high-performance aircraft only and new transponder costs for both the high- and low-performance aircraft.

The SAB concept evaluated and for which costs were estimated is designed to operate in an ATCRBS environment with conventional replies, and in a selective addressing mode when interrogated by a SAB ground station. Since all features of ATCRBS operation are required in the transponder, the SAB concept enhances the existing equipment capability rather than replacing any capability. The data processing required for SAB operation includes decoding of the interrogator data stream, error detection through the use of the Hamming code, comparison of the transmitted address with own-code address, and decoding the requested reply (i.e., identity or altitude). The reply format for SAB operation is identical to the ATCRBS format and can be generated by either the ATCRBS encoder logic or SAB logic. Because of the suppression characteristics of existing transponders, the reply encoding is generated as part of the SAB logic in the adapter configuration. In new SAB transponders, this function is common to both the ATCRBS and SAB modes of operation.

4.2.1 Modification to Existing Avionics

The equipment required in support of the 4096 SAB concept consists of four modules (printed circuit cards) containing the electronics necessary to process, decode, and evaluate the interrogator data and encode the appropriate reply on recognition of its own address. The RF, IF, and transmitter functions, as well as certain control and clock functions required for a complete transponder operation, are reused in the ATCRBS avionics with all necessary signal interfaces available at the connectors of the ATCRBS transponder. The four modules are housed in a 1/8-ATR short enclosure designed to ARINC characteristics for air transport equipment cases. Table 4-3 presents the cost development of the SAB adapter as a function of module costs, final assembly and test, and total unit cost. The cost estimating method is the same as was used in Section 4-1. Material costs based on a detailed parts lists and labor hour estimates for manufacturing and assembly of each module are presented in Appendix B to this report. The estimated selling price of $1200 is the expected cost to the air carriers and distributors who usually purchase in large quantities directly from the manufacturer. The list price of $1561 is the expected cost to the private aircraft owners requiring high-performance avionics. The addition of this SAB adapter to an existing ATCRBS system would constitute the entire complement of avionics necessary for SAB operation.

Table 4-3. COST DEVELOPMENT, 4096 SAB ADAPTER, HIGH-PERFORMANCE AIRCRAFT (IN DOLLARS)						
Cost Category \ Module	Comparator Control Clocks	Data Decoder	Encoder and Control	Power Supply	Chassis and Assembly	Total
Material Cost	75.13	140.14	55.25	24.60	40.40	335.52
Material Handling @ 25% Material Cost	18.78	35.04	13.81	6.15	10.10	83.88
Labor @ $11.00/Hour	13.57	13.19	25.29	12.07	48.04	112.16
Burden @ 135% Labor	18.32	17.81	34.14	16.29	64.85	151.41
Inspection @ 5% Labor/Burden	1.59	1.55	2.97	1.42	5.64	13.17
Subtotal	127.39	207.73	131.46	60.53	169.03	696.14
Engineering and Q.C. @ 25%	31.85	51.93	32.87	15.13	42.26	174.04
Factory Cost	159.24	259.66	164.33	75.66	211.29	870.18
General and Administrative @ 20%	31.85	51.93	32.87	15.13	42.26	174.04
Total Direct Cost	191.09	311.59	197.20	90.79	253.55	1044.22
Profit @ 15%	28.66	46.74	29.58	13.62	38.03	156.63
Selling Price	219.75	358.33	226.78	104.41	291.58	1200.85
Distribution @ 30%	65.93	107.50	68.03	31.32	87.47	360.25
List Price	285.68	465.83	294.81	135.73	379.05	1561.10

4.2.2 Development of New Avionics

The addition of the SAB features to the ATCRBS concept is more complex than replacement of the decoding and encoding cards, as was possible in the one-out-of-eight concept. All necessary SAB functions can be accomplished through conventional logic circuitry that can be packaged on either one large or two boards of standard size (i.e., similar to existing PC boards in transponders). The power supply and encoder and control circuitry necessary for the 4096 adapter concept are not required when SAB is incorporated into a single unit, because the basic transponder has those capabilities. The functions can be properly integrated as a design change rather than added on as a field modification.

This section develops the costs of both the high-performance and low-performance aircraft avionics required for SAB operation. Consistent with the normal practice in the avionics industry, maximum use of existing field-proven modules has been made in the assembly of the SAB/ATCRBS transponders.

4.2.2.1 High-Performance Aircraft Avionics

A standard transponder designed to ARINC Characteristic 572 is housed in a 3/8-ATR enclosure. The addition of two printed circuit card modules for SAB data processing will require an enclosure either of the ATR-long or the next larger ATR standard size. For purposes of this study, use of the 3/8-ATR long version has been assumed to facilitate replacement in standard avionics bays without relocation of other avionics. Table 4-4 presents the cost development of the SAB transponder modules. All modules except the SAB comparator and SAB data decoder modules are basically identical to those presently employed in ATCRBS transponders. Minor changes affecting control circuitry and encoder enabling were incorporated in the design and cost analysis of the assemblies. The design of existing modules can be obtained from manuals on modern transponders. Parts lists based on these designs and the estimated labor hours for manufacturing and assembly of each module are included in Appendix B. The resultant selling price of $4558 is approximately 15 percent higher than the present cost of an ATCRBS transponder. System operation would require a standard control unit priced at $516 and an antenna priced at $63 (those costs are from manufacturer's price lists), for a total system cost of $5137 to an air carrier aircraft or a distributor. The comparable cost to a private owner requiring high-performance avionics would be $6517.

4.2.2.2 Low-Performance Aircraft Avionics

Single and light twin-engine aircraft are often under the positive control of ATC and have unique codes assigned for radar tracking. When operating under such control, the onboard transponders are subject to the generation of synchronous garble causing loss of surveillance by the ground systems. In order to eliminate the problem and improve flight safety to these aircraft, a low-cost version of the SAB transponder must be made available. This section develops the cost of a SAB transponder intended for the low-performance aircraft community based on the logic design developed for the high-performance class of aircraft but using avionics design practices and environmental requirements of the general aviation community. Table 4-5 presents the cost development of the modules and system making up the SAB transponder. The modules, except for the SAB PC board, are patterned after an existing general aviation transponder and contain all the functions necessary for ATCRBS operation. A single, large, printed circuit board containing all the logic components necessary for SAB operation has been added to the ATCRBS modules and integrated into the transponder functions. The logic design supporting the SAB addition is the same as for the high-performance avionics and is presented in Appendix A. The cost development method is similar to that

Table 4-4. COST DEVELOPMENT, 4096 SAB TRANSPONDER, HIGH-PERFORMANCE AIRCRAFT (IN DOLLARS)

Module / Cost Category	Transmitter	Receiver	IF Amplifier	Video Processor	Control Matrix	Monitor	ATCRBS Decoder	ATCRBS Encoder	SAB Comparator	SAB Data Decoder	Power Supply	Chassis	Final Assembly	Total
Material Cost	265.70	229.93	47.16	93.70	73.02	86.76	70.86	67.77	73.79	140.14	54.24	66.71	-	1269.78
Material Handling @ 25% Material Cost	66.43	57.48	11.79	23.43	18.26	21.69	17.72	16.94	18.45	35.04	13.56	13.56	-	314.35
Labor @ 11.00/Hour	28.73	54.30	20.31	41.10	60.92	32.12	16.48	16.10	12.89	13.19	22.47	67.64	42.63	428.88
Burden @ 135% Labor	38.79	73.30	27.41	55.48	82.24	43.36	22.25	21.74	17.40	17.81	30.34	91.31	57.54	578.97
Inspection @ 5% Labor/Burden	3.38	6.38	2.39	4.83	7.16	3.77	1.94	1.89	1.51	1.55	2.64	7.95	5.01	50.40
Subtotal	403.03	421.39	109.06	218.54	241.60	187.70	129.25	124.44	124.04	207.73	123.25	247.17	105.18	2642.38
Engineering and Q.C. @ 25%	100.76	105.35	27.27	54.64	60.40	46.93	32.31	31.11	31.01	51.93	30.81	61.79	26.29	660.60
Factory Cost	503.79	526.74	136.33	273.18	302.00	234.63	161.56	155.55	155.05	259.66	154.06	308.96	131.47	3302.98
General and Administrative @ 20%	100.76	105.35	27.27	54.64	60.40	46.93	32.31	31.11	31.01	51.93	30.81	61.79	26.29	660.60
Total Direct Cost	604.55	632.09	163.60	327.82	362.40	281.56	193.87	186.66	186.06	311.59	184.87	370.75	157.76	3963.58
Profit @ 15%	90.68	94.81	24.54	49.17	54.36	42.24	29.08	28.00	27.91	46.74	27.73	55.61	23.67	594.54
Selling Price	695.23	726.90	188.14	376.99	416.76	323.80	222.95	214.66	213.97	358.33	212.60	426.36	181.43	4558.12
Distribution @ 30%	208.57	218.07	56.44	113.10	125.03	97.14	66.89	64.40	64.19	107.50	63.78	127.91	54.43	1367.45
List Price	903.80	944.97	244.58	490.09	541.79	420.94	289.84	279.06	278.16	465.83	276.38	554.27	235.86	5925.57

Table 4-5. COST DEVELOPMENT, 4096 SAB TRANSPONDER, LOW-PERFORMANCE AIRCRAFT

Cost Category	Module Cost in Dollars						
	Transmitter	Receiver	Main PC Board	SAB PC Board	Chassis and Enclosure	Assembly and Test	Totals
Material Cost	31.02	32.37	53.65	54.34	23.78	-	195.16
Material Handling (10%)	3.10	3.24	5.37	5.43	2.38	-	19.52
Labor ($3.25 per hour)	5.10	15.80	19.68	5.63	2.29	11.25	59.75
Subtotal	39.22	51.41	78.70	65.40	28.45	11.25	274.43
Overhead, G and A, and Profit (67%)	26.28	34.44	52.73	43.82	19.06	7.54	183.87
Factory Selling Cost	65.50	85.85	131.43	109.22	47.51	18.79	458.30
Distributor Markup (100%)							458.30
List Price							916.60

used for high-performance avionics but the factors determining the factory selling price are different, reflecting the practice of the general aviation manufacturers. The labor rates are not loaded and the overhead, G and A, and profit are combined to compute a markup over the factory cost (subtotal in Table 4-3). This factory selling cost is the price paid by distributors who resell to individual aircraft owners. A 100-percent markup over the factory selling price establishes the list cost to the aircraft owners. The system cost would include the price of an antenna at $13 for a total cost of $930, or a 50-percent increase over present ATCRBS transponder costs. The control function of a general aviation transponder is built into the electronics package.

4.3 SUMMARY OF AVIONICS COSTS

The equipment costs developed in this chapter cover the two SAB concepts proposed for the appropriate community of users. Implementation provisions for adopting each concept to either existing systems or new systems were considered and are reflected in the cost of modification packages and new avionics. Equipment and costs covering both provisions were developed for the high-performance aircraft as likely candidates for implementation and as new avionics for the 4096 SAB concept for the low-performance general aviation aircraft, since modifications or retrofits to existing systems are not normally practical for them. Table 4-6 summarizes the costs of avionics developed in this study and presents the expected selling price to each of the three classes of users; air carriers, high-performance general aviation, and low-performance general aviation. Complementary equipment shown in the table either exists on aircraft being retrofitted with adapters or must be acquired at the costs shown for system installation on new or unequipped aircraft.

Table 4-6. ACQUISITION COST OF SAB AVIONICS

Equipment	Cost (in dollars) by User Category		
	Air Carrier	High-Performance General Aviation	Low-Performance General Aviation
One-Out-of-Eight System			
SAB Adapter	572	743	N/A
SAB Transponder	4144	5388	N/A
4096 System			
SAB Adapter	1201	1561	N/A
SAB Transponder	4558	5926	917
Complementary Equipment			
Control*	516	516	N/A
Antenna*	63	75	13

*From manufacturers' price lists.

CHAPTER FIVE

INSTALLATION DATA

This chapter addresses the development of those items employed in the economic analysis of the SAB concept. The data items include the specific SAB equipment configurations for each category of user, the cost of installing SAB for each category of user, and aircraft population projections within each user category. The data developed and identified in this chapter will be used in Chapter Six in exercising a life-cycle cost model to establish the first-year-of-ownership costs to each of the user categories.

5.1 DISTRIBUTION COST

In Chapter Four, the factory selling prices and the list prices for the equipments were estimated. It is common practice for the commercial airlines and distributors to obtain SAB equipments directly from the manufacturers, but the general aviation community has to pay additional money to avionics distributors as a part of the acquisition cost for the SAB units. To account for this added expense, this study included a 100-percent mark-up of the factory selling price for low-performance units to determine the list price. However, many distributors who do not install equipment advertise discounts on new factory-warranted equipment. The advertised discounts vary depending on demand and availability, but are generally between 10 and 30 percent. A 20-percent has been applied to the low-performance aircraft equipment evaluated in this study, reflecting the mean of the advertised discounting practice in the general aviation community when a unit is purchased separately (installation would then be an additional expense).

A 30-percent markup of high-performance aircraft units was applied to the units installed in general aviation aircraft. These values are representative of the distribution costs found in the general aviation community.

Distribution costs were also considered as a logistic support cost associated with the replacement of modules or component parts. The distribution costs of the individual replacement parts were computed as a percentage of the component's cost, with a distribution markup of 30 percent for high-performance aircraft avionics components and 60 percent for low-performance aircraft avionics components.

5.2 AIRCRAFT CONFIGURATIONS

The complement of equipment to be installed by each user depends on individual needs, the probable flight profiles, the required operational availability (especially for the air carriers), and the anticipated or required flight crews for special classes of aircraft.

This section identifies the probable SAB aircraft configurations for each class of user on the basis of existing practices in the aviation community related to flight-critical avionic equipment.

5.2.1 Commercial Aviation

The air carrier practice of achieving high operational availability through system redundancy is assumed not to be applicable to the SAB implementation. Rather, a minimum configuration necessary to meet operational requirements is specified. Therefore, all certified commercial air carriers are assumed to require the following complement of SAB avionics:

- One-Out-of-Eight-Concept - Existing Fleet
  - 1 set of SAB adapter electronics
- One-Out-of-Eight Concept - New Aircraft
  - 1 set of SAB transponder electronics
  - 1 antenna (bottom mounted)
  - 1 set of control equipment
- 4096 SAB Concept - Existing Fleet
  - 1 set of SAB adapter electronics
- 4096 SAB Concept - New Aircraft
  - 1 set of SAB transponder electronics
  - 1 antenna (bottom mounted)
  - 1 set of control equipment

The electronics will be located in the avionics bay of the aircraft. For retrofit installations, the probable location relative to the existing transponder is shown in Figures 5-1 and 5-2. The control system will be tailored to the specific air frame and the system chosen for implementation. A single set of SAB electronics has been assumed for commercial air carriers to be consistent with the installation decisions generally made for transponders. Some air carrier aircraft may be equipped with dual installations, but the cost of such a decision is not considered in this study.

5.2.2 General Aviation

The private aircraft owner is usually cost-conscious, carrying the minimum avionics required consistent with flight regulations and safety. Therefore, it has been assumed in this study that almost all (95 percent) of private aircraft owners will prefer to install the least expensive SAB.

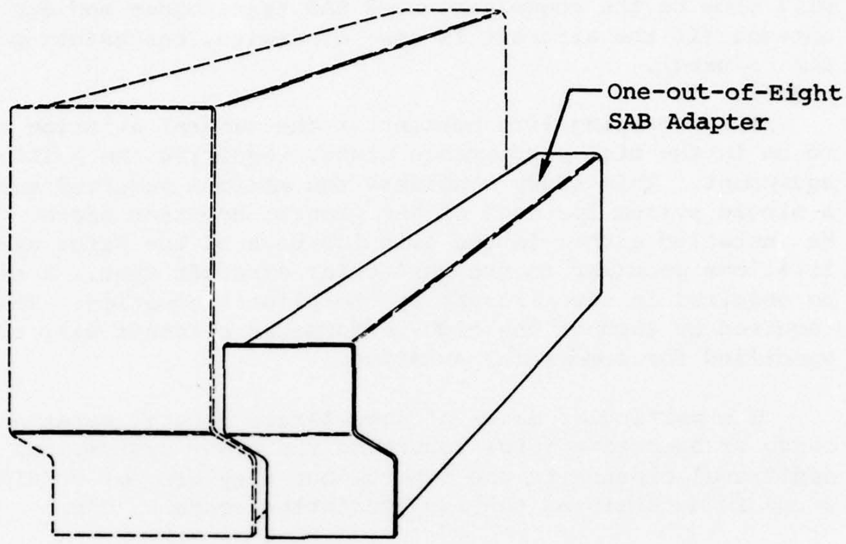

Figure 5-1. LOCATION OF ONE-OUT-OF-EIGHT SAB ADAPTER RELATIVE TO EXISTING ATCRBS TRANSPONDER

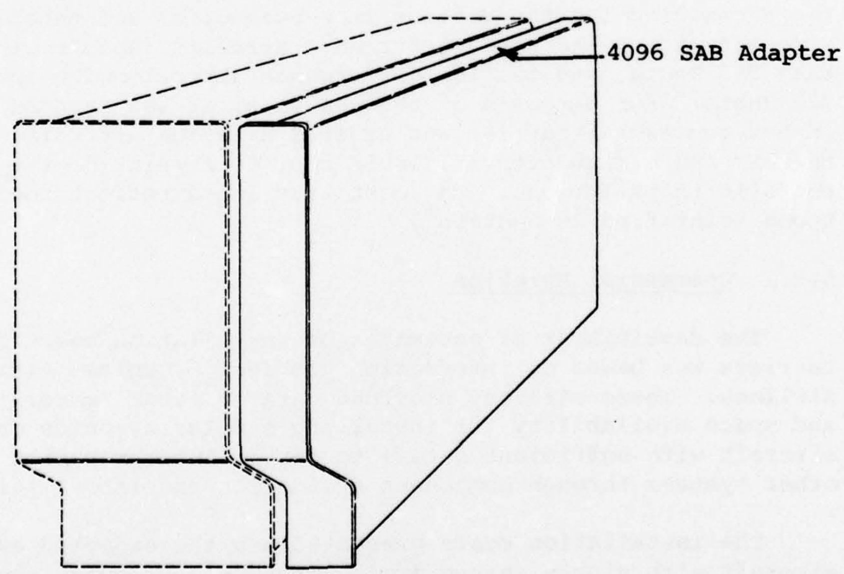

Figure 5-2. LOCATION OF 4096 SAB ADAPTER RELATIVE TO EXISTING ATCRBS TRANSPONDER

The assumed hardware consists of a single set of electronics with built-in controls intended for installation in the flight console of the aircraft. The equipment required for this 95 percent of the population will thus be the console-mounted SAB transponder and one bottom-mounted antenna (if the aircraft is new; otherwise, the existing ATCRBS antenna can be used).

The remaining five percent of the general aviation aircraft are assumed to be in the high-performance class, requiring the ARINC-characteristic equipment. This study considers the minimum required equipment and recommends a single system for each of the general aviation users. The equipment will be installed either in the avionics bays of the large airframes or at remote locations peculiar to the particular aircraft type. A single control will be required in new aircraft at the pilot's position. The minimum equipment required by each of the high-performance aircraft will be the same as specified for commercial aviation.

The particular needs of some larger general aviation aircraft (e.g., cargo or executive jets) requiring redundant systems can be satisfied at additional expense to the owners, but they are not considered in this study in determining the implementation costs of SAB.

5.3 INSTALLATION COSTS

The cost of equipment installation considered in this study falls into two categories: (1) retrofit of the existing fleet, and (2) implementation in new aircraft. Installation costs have been developed for each of these two categories for the various user categories and general classes of aircraft, i.e., the high-performance aircraft capable of speeds greater than 250 knots, and the low-performance aircraft with speeds lower than 250 knots. For purposes of the analysis, it was assumed that installation in new commercial carrier and general aviation aircraft, when performed by the air frame manufacturer, would cost 60 percent of the estimated cost of retrofit installations. The costs developed reflect the equipment configurations identified in Section 5.2.

5.3.1 Commercial Aviation

The development of estimates of installation costs for the commercial carriers was based on information provided by United Airlines and Piedmont Airlines. These airlines provided data on labor, materials, engineering, and space availability for installing similar avionics on B-727 and B-737 aircraft with sufficient detail to permit interpretation and adaptation to other systems through component evaluation and labor estimation.

The installation costs presented are the expected average costs per aircraft with single system implementation. Adequate space is assumed to accommodate the adapters necessary for either SAB concept when retrofitting existing aircraft. Those airlines choosing new SAB transponders for existing aircraft would replace, without modification, the existing ATCRBS transponder for the one-out-of-eight concept, or change the depth of the

wiring harness in the airframe to accept the ATR-long version of avionics for the 4096 concept. No additional installation would be required to implement either SAB transponder in existing aircraft.

The cost breakdown for system retrofit by installing the SAB adapters in the commercial aviation case is as follows:

Installation Factor	Time Required	Cost
Shelf Fabrication and Installation	24 hours	$534
On-Aircraft Cabling	4 hours	89
Engineering	1 hour	22
Material	-	50
Totals	29 hours	$695

The cost breakdown for installing the SAB transponder on existing aircraft without ATCRBS capability in the commercial aviation case is as follows:*

Installation Factor	Time Required	Cost
Shelf Fabrication and Installation	48 hours	$1067
Antenna Installation	12 hours	267
Control Installation	1 hour	22
On-Aircraft Cabling	100 hours	2222
Engineering	3 hours	66
Material	-	516
Totals	164 hours	$4160

5.3.2 General Aviation

The installation costs for high-performance general aviation aircraft have been developed from the experience of Piedmont Airlines. (Piedmont maintains and installs avionic equipment in corporate aircraft.) The resultant costs have been averaged to reflect the various classes and configurations anticipated in high-performance general aviation aircraft.

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*Note: Air carriers are not allowed to operate without ATCRBS, but these costs were computed because they provide a basis for estimating the cost of installing SAB on new aircraft.

The installation of either version of the SAB transponder in aircraft with ATCRBS capability would be accomplished without modification to existing aircraft configurations. The installation of the adapter to complement the ATCRBS transponder operation would result in the following costs:

Installation Factor	Time Required	Cost
SAB Adapter Installation	2 hours	$ 36
Aircraft Wiring	4 hours	72
Material	-	50
Totals	6 hours	$158

The cost breakdown for installing the SAB transponder on existing aircraft without ATCRBS capability in the high-performance general aviation case is as follows:

Installation Factor	Time Required	Cost
SAB Electronics Installation	24 hours	$ 430
Antenna Installation	12 hours	215
Control Installation	2 hours	36
Cabling	40 hours	715
Material	-	516
Totals	78 hours	$1912

The installation costs for single-engine and light twin-engine aircraft were developed through a survey of the maintenance facilities supporting the general aviation community. All FAA-certified repair facilities were requested to provide an estimate on the installation of a NARCO DME-190. The DME-190 was chosen as being similar in size and complexity to the proposed SAB transponder, requiring similar cabling, antenna, and power. The questionnaire further requested a breakdown in hours of the effort required for unit installation, antenna installation, cabling, average material cost, and installation and repair labor rates. Replies were received from more than 25 percent of the repair facilities and are considered representative of the entire general aviation community. A summary of the questionnaire replies is contained in *Cost Analysis of Airborne Collision Avoidance Systems (CAS) Concepts*.*

The time and cost data in this section are taken from the results of the survey. The installation costs are averages and reflect the variety of airframes encountered by the responding facilities. A complexity factor has been used on the cabling estimate to allow for the additional labor for connecting the encoding altimeter, assumed to be a part of the existing aircraft avionics.

**Cost Analysis of Airborne Collision Avoidance System (CAS) Concepts*, Report No. FAA-EM-76-1, dated December 1975, hereinafter referred to as FAA-EM-76-1.

The cost data for existing general aviation aircraft are:*

Installation Factor	Time Required	Cost
GA Unit Installation	4.89 hours	$ 81
Antenna Installation	2.50 hours	41
Cabling	5.00 hours	81
Material	-	23
Totals	12.39 hours	$226

5.3.3 Installation Cost Summary

Table 5-1 presents a summary of the installation costs developed in this section and used in determining the cost of the first year of ownership evaluated in Chapter Six. Because of similarity in size and wiring complexity between the one-out-of-eight and 4096 SAB equipments the installation costs for both concepts are assumed to be the same. New aircraft installation costs are assumed to be 60 percent of the developed retrofit costs for existing aircraft.

Table 5-1. SUMMARY OF INSTALLATION COSTS (PER AIRCRAFT) (IN DOLLARS)

System	Air Carriers	High-Performance General Aviation	Low-Performance General Aviation
Retrofit Installations			
SAB Adapter	695	158	N/A
SAB Transponder	4160*	1912*	226*
New Aircraft Installations			
SAB Transponder	2496**	1147**	136**

*These costs would be practically zero for aircraft presently having an installed ATCRBS transponder.

**These are identical to the costs that would be borne if an ATCRBS transponder were installed in new aircraft.

5.4 ARINC RESEARCH SCENARIOS

The development of first year-of-ownership costs to the users requires identification of the number of aircraft subject to retrofit of the SAB systems, and the number of projected new aircraft that would have SAB avionics installed in place of the conventional ATCRBS systems. This

*These costs were computed because they provide a basis for estimating the cost of installing SAB on new aircraft.

section presents the secenarios used in the study for each type of equipment to be installed by each user community and the expected period of system implementation. In addition, the aircraft population statistics are presented that are used in the life-cycle-cost model evaluation described in Chapter Six.

For purposes of this study, the retrofit period for the general aviation community requiring high-performance avionics has been assumed to be eight years, starting in 1978. The SAB installation program has been assumed to affect only those aircraft not scheduled for retirement during the retrofit period. For all user categories, it has been assumed that retrofitting would be accomplished at a constant rate, with all existing high-performance aircraft being equipped with SAB by the end of 1985. All new aircraft delivered in 1978 and in later years would have the SAB transponder avionics installed as part of the original required equipment.

The aircraft population projections used in this study have been based on information developed in 1974 by the U.S. Department of Transportation, FAA, Office of Aviation Policy, Aviation Forecast Branch. The 1974 statistics were used to provide data comparable to other evaluations of alternatives which were based on the 1974 data.

5.4.1 Commercial Aviation

It is assumed that the air carriers' retrofit period will be four years, and all aircraft not scheduled for retirement within the first four years will be retrofitted with the adapter version of SAB. All new aircraft would have SAB capability incorporated in the transponder. Table 5-2 portrays the projected population of commercial aircraft, with expected expansions and retirements used in the analysis.

5.4.2 General Aviation

General Aviation is the largest and fastest-growing element of the aviation community. Its population extends from large, pure-jet cargo fleets through executive and corporate aircraft to air taxis and privately owned pleasure aircraft. The sizes and types of aircraft are as numerous as the variety of uses to which they are subjected. The FAA reported more than 150,000 general aviation aircraft registered in 1974. The general aviation community has also been divided into high- and low-performace categories. For purposes of this study, and on the basis of sampled data on new aircraft production, 10 percent of the multi-engine aircraft were assumed to be in the high-performance category. An eight-year linear retrofit of general-aviation high-performance aircraft has been assumed for the analysis. All new low-performance aircraft delivered starting in 1978 are assumed equipped with the 4096 SAB transponders. Existing low-performance aircraft are not expected to participate in the SAB concept.

Table 5-3 projects general aviation population data by engine configuration and date for the period considered in the life of the study. The eight-year retrofit program identifies the quantities of both types of SAB equipment that will be required to satisfy the needs of the community and takes into consideration the 5-percent high-performance and 95-percent low-performance aircraft avionics deployment dictated by aircraft.

Table 5-2. COMMERCIAL CARRIER AIRCRAFT STATISTICS

Year	Existing	New	Retirements	Total
1978	2,848	133	50	2,931
1979	2,931	157	69	3,019
1980	3,019	142	67	3,094
1981	3,094	180	102	3,172
1982	3,172	149	78	3,243
1983	3,243	142	69	3,316
1984	3,316	130	63	3,383
1985	3,383	119	53	3,449
1986	3,449	65	0	3,514
1987	3,514	64	0	3,578
1988	3,578	65	0	3,643
Totals	-	1,346	551	-

Table 5-3. GENERAL AVIATION AIRCRAFT STATISTICS*

Year	Single Engine		Multiengine		Turbine		Total New	Total
	Existing	New	Existing	New	Existing	New		
1978	140,300	4,200	22,600	1,100	4,900	400	5,700	173,500
1979	144,500	4,000	23,700	1,200	5,300	600	5,800	179,300
1980	148,500	4,100	24,900	1,100	5,900	500	5,700	185,000
1981	152,600	5,100	26,000	1,200	6,400	400	6,700	191,700
1982	157,700	4,900	27,200	1,200	6,800	600	6,700	198,400
1983	162,600	4,800	28,400	1,300	7,400	600	6,700	209,100
1984	167,400	4,500	29,700	1,600	8,000	700	6,800	211,900
1985	171,900	5,500	31,300	800	8,700	300	6,600	218,800
1986	177,400	5,500	32,100	800	9,000	300	6,600	225,100
1987	182,900	5,500	32,900	800	9,300	300	6,600	321,700
1988	188,400	5,500	33,700	800	9,600	300	6,600	258,300
Totals	-	53,600	-	11,900	-	5,000	70,500	-

*These statistics do not include gliders, experimental aircraft, rotorcraft, etc.

CHAPTER SIX

INDIVIDUAL AIRCRAFT COSTS FOR SAB IMPLEMENTATION

The cost of implementing the two SAB concepts for the various users of the national airspace are presented in this chapter. The analyses are based on the data developed in Chapters Four and Five and FAA-EM-76-1 and are performed with the assistance of a cost model. Implementation-cost data are shown by individual aircraft for two sets of data: data developed for the one-out-of-eight SAB concept, and data developed for the 4906 SAB concept.

6.1 COST MODEL

ARINC Research Corporation's Economic Analysis Model* (EAM) has been adapted to evaluate the cost impact of proposed selective address beacon systems and to provide a basis for cost comparison among the several alternatives of the upgraded third-generation ATC systems.

The model evaluates the cost impact and provides a basis for comparing costs among the different users: commercial aviation, high-performance general aviation, and low-performance general aviation. The distribution of the types of SAB systems within a specific user category is specified by the data provided to the model.

The model has been programmed in FORTRAN for use with a computer time-sharing system. It computes the expected annual and cumulative acquisition, installation, and logistic support costs for each combination of concept and user desired. The program is flexible so that data can be readily changed, sensitivity evaluations performed, or additional data outputs obtained.

The program features and mathematical formulation of the EAM are documented in FAA-EM-76-1.

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*Developed for cost analysis of a Proposed Defense Navigation Satellite System Receiver, prepared for USAF Space and Missile Systems Organization under Contract F09603-73-A-0933-TB01 by ARINC Research Corporation.

6.2 ADDITIONAL INPUTS REQUIRED BY THE MODEL

The information developed in Chapter Four on costs and in Appendix B on reliability and material-to-repair costs, together with the statistical data developed in Chapter Six, constitute only a portion of the data required to calculate the cost of implementation.

Many parameters contributing to the evaluation of the system life-cycle costs are dictated by the user communities. For example, the average hours flown by a user vary from 17.3 hours per month for the general aviation equipment to 238 hours per month for the air carrier equipment. These data were developed, as were other parameters required by the model, through contact with the user community (e.g., United and Piedmont Airlines, Aircraft Owners and Pilots Association, and Air Transport Association), research work completed through other contracts within the Corporation, and information furnished by the FAA.

A complete list of the parameters influencing the evaluation is presented in tabulated format for ready comparison in Appendix E of FAA-EM-76-1. All the parameters considered influential in evaluating the relative costs and reliabilities of the systems have been programmed into the cost model and the acquisition, installation, and nonrecurring logistics support costs determined by the model. The recurring logistics support costs output of the model has been exercised for first-year-of-ownership only.

6.3 RESULTS OF APPLYING THE COST MODEL

The ARINC Research EAM computes annual and cumulative acquisition, installation, and logistic support costs for each combination of equipment and user desired.

This section presents the results derived from the model on the basis of the parametric inputs developed in this study and adapted from past studies (see FAA-EM-76-1). The results are presented on a per-aircraft basis to identify separately the costs of acquisition and installation, and nonrecurring and recurring logistics costs expected by an aircraft owner in any of the user categories.

The per-aircraft cost of the first year of ownership of a selective address beacon system consists of the initial acquisition and installation costs, a proportion of the nonrecurring logistic support costs (determined by averaging over the entire user population in a life cycle), and the recurring yearly logistics costs attributed to an aircraft. These costs can be combined to provide a competitive evaluation of the systems.

Acquisition costs include the equipment costs developed in Chapter Four for aircraft configurations identified in Chapter Five. This section presents the cost of ownership per aircraft for the existing fleet of

high-performance aircraft, the majority of the expected aircraft requiring SAB, and the cost of ownership per aircraft for new aircraft introduced in 1978 and later years. All new aircraft delivered after 1978 are expected to be equipped with the transponder version of SAB, and would not require the SAB adapters. Low-performance general-aviation aircraft are considered candidates for new 4096 SAB transponders only; there is little probability that the existing fleet of aircraft will be modified.

The logistic support costs are divided into two categories: the nonrecurring costs associated with introduction of a new system and the recurring costs experienced from normal maintenance of the system. These costs are categorized into the following cost elements:

- On-aircraft maintenance
- Off-aircraft maintenance
- Spare parts
- Inventory management
- Support equipment
- Training
- Technical data and failure documentation
- Facilities

All these cost elements contribute to the recurring logistics costs and all but the on- and off-aircraft maintenance elements contribute to the nonrecurring logistics costs. For example, spare parts would normally be purchased by a user and introduced into the inventory system. This would result in costs associated with the spares and the costs of inventory set-up, both considered as nonrecurring. Upon failure of a unit, spares would be used up and replacement spares ordered, generating a recurring cost of parts and documentation. The EAM computes these types of costs on the basis of the probability of failure.

The logistic support costs for the general aviation community are limited to the recurring costs of maintenance, i.e., on- and off-aircraft maintenance costs consisting of labor and materials to repair a failed unit. The individual general aviation owner is not expected to stock either spare parts or test equipment, and consequently does not usually incur the management or facility costs associated with maintaining an inventory.

6.3.1 Commercial Aviation

Table 6-1 compares the per-aircraft costs of system implementation for the two SAB concepts considered in the study. The table shows the acquisition, installation, and estimated portion of the nonrecurring and recurring logistic costs shown in 1975 dollars, to be incurred for SAB

equipment installed in 1978. The first year of ownership, therefore, is 1978. The logistics costs associated with the adapter versions of both concepts consider support of the avionics added to existing transponders. Therefore, the costs shown are the additional costs above the support costs of existing transponders. In the case of the transponder versions of both SAB concepts, the logistic support costs are the total expected expenditures associated with operation of the airborne portion of a surveillance system.

Table 6-1. COMMERCIAL AVIATION COST DATA COMPARISON - (SINGLE SYSTEM PER AIRCRAFT - IN 1975 DOLLARS)

Cost Factors	One-Out-of-Eight SAB Adapter (Retrofit Aircraft)	One-Out-of-Eight SAB Transponder (New Aircraft)	4096 SAB Adapter (Retrofit Aircraft)	4096 SAB Transponder (New Aircraft)
Acquisition	572	4723*	1201	5137*
Installation	695	2496	695	2496
Nonrecurring** Logistics	31	393	56	413
Recurring** Logistics	12	372	43	387
First Year of Ownership	1310	7984	1995	8433

*Includes transponder, control, and antenna.
**For method of developing recurring and nonrecurring logistics costs and common data inputs, see FAA Report EM-76-1.

6.3.2 General Aviation

The data in Table 6-2 identify the cost of the first year of ownership of each SAB concept for high-performance general aviation aircraft and the cost of the first year of ownership of the 4096 SAB concept for new low-performance general aviation aircraft. A majority of existing low-performance general aviation aircraft are equipped with ATCRBS transponders. This study assumed that those aircraft will be converted to the SAB mode of operations through attrition rather than through retrofit. Such conversion would have negligible installation cost. The acquisition costs include the distribution costs expected in a competitive market for the SAB equipment. Nonrecurring costs (e.g., spares inventory) are not included since they do not apply to the private general aviation owner. The low recurring logistics costs for each system are the result of a limited average number of flight hours per month. For some classes of the high-performance general aviation community (e.g., corporate or cargo jet aircraft) these costs will increase considerably. However, the typical aircraft owner equipped with SAB avionics is expected to experience the indicated average maintenance costs.

Table 6-2. GENERAL AVIATION COST DATA COMPARISON (SINGLE SYSTEM PER AIRCRAFT - IN 1975 DOLLARS)					
Cost Factors	High-Performance Aircraft				Low-Performance Aircraft
	One-Out-of-Eight SAB Adapter (Retrofit Aircraft)	One-Out-of-Eight SAB Transponder (New Aircraft)	4096 SAB Adapter (Retrofit Aircraft)	4096 SAB Transponder (New Aircraft)	
Acquisition	743	5979*	1561	6517*	746**
Installation	158	1147	158	1147	136
Recurring Logistics	1	172	2	174	16
First Year of Ownership	902	7298	1721	7838	898

*Includes transponder, control, and antenna.
**Includes transponder and antenna.

6.4 IMPACT OF SAB IMPLEMENTATION ON THE AVIATION COMMUNITY

This study has treated the introduction and implementation of a SAB system as an independent requirement on the users of the NAS. However, only the adapters to existing avionics or those portions peculiar to SAB in new avionics should constitute a cost applicable directly to SAB implementation. An aircraft considered as a candidate for SAB is required to carry ATCRBS transponders when operating in the NAS. The SAB transponder would satisfy this requirement and provide additional surveillance capability. The data presented in Tables 6-1 and 6-2 for new aircraft must be treated with the realization that the installation and logistics support costs shown for SAB are almost identical to the expected costs for installation and logistics support of ATCRBS, which the SAB would replace. The acquisition costs of SAB are slightly higher because of greater capability of the equipment, but the costs directly attributable to SAB implementation are the differentials between the costs developed for SAB and the costs of ATCRBS avionics. The differentials for high-performance aircraft avionics are a 3-percent increase in acquisition costs for the one-out-of-eight SAB systems and a 10-percent increase in acquisition costs for the 4096 SAB systems. For low-performance aircraft avionics, the increase in acquisition cost for the 4096 SAB system is 50 percent because of the relative increased complexity of SAB over the existing ATCRBS transponders. The first-year-of-ownership costs in the high-performance category would increase by 2.4 and 8 percent, respectively, over the expected costs of ATCRBS, and, in the low-performance category, the increase in costs would be 36 percent over the comparable ATCRBS system.

CHAPTER SEVEN

STUDY CONCLUSIONS

The study has shown that a cost-effective SAB system can be developed and implemented to reduce the effects of synchronous garble in the dense terminal environment. Of the two SAB concepts identified in the study, the one-out-of-eight concept provides the highest potential for early implementation since it has the least impact on both airborne and ground systems. However, the concept provides only a sevenfold reduction in synchronous garble and should be considered as only an interim solution before introduction and implementation of more sophisticated surveillance systems such as DABS.

The 4096 SAB concept was designed to meet the present and future needs of surveillance systems in eliminating synchronous garble and providing increased communications capability for aircraft detection and tracking in the national air space. Although more complex than the other concept, the 4096 SAB provides the capability to selectively address every aircraft assigned a unique transponder code whose avionics have been either modified or replaced with SAB-compatible equipment. This concept should be viewed as an alternative, long-range solution to aircraft surveillance problems in place of the more sophisticated DABS concept. The 4096 SAB offers the benefits of lower costs of system implementation, ability to modify existing ground interrogation systems rather than replace them, early implementation in areas experiencing severe synchronous garble problems, and an orderly transition from ATCRBS to SAB operations by virtue of cost-effective modification packages complementing existing avionics on high-performance aircraft.

7.1 RESULTS OF THE OPERABILITY EVALUATION

Chapter Three addressed the expected improvements in aircraft identification that can be obtained from implementation of either SAB concept. A probabilistic approach was used to determine the possibility of two or more aircraft having the same code, with the results showing a very low probability of occurrence for the respective applications.

The ability of each concept to handle all aircraft in the main beam of the radar and in the terminal environment was investigated. It was determined that the capacity of each concept would be limited by the constraints of existing ground equipment and operational procedures.

However, even with these constraints, both concepts were shown to be effective in reducing the synchronous garble in today's terminal environment. Careful redesigns and minor modifications to ground interrogations could greatly increase the capacity of the system (e.g., increasing PRF) without the need for major replacements.

Finally, the communication reliability of the system operating in the SAB mode was shown to be sufficiently high to provide confidence in its ability to selectively address an aircraft and receive the desired reply. Normal surveillance in present ATCRBS modes would still provide identity, altitude, and bearing information, with the SAB addition enhancing the operation in situations that present equipments cannot handle. The addition of SAB to existing operations would further improve surveillance effectiveness.

7.2 AIRBORNE SYSTEM IMPLEMENTATION COSTS

The results of the cost analysis of SAB implementation are presented in Table 7-1. The costs shown are the expected totals for system acquisition, installation, and operation for the first year of ownership by both individual aircraft owners and fleet operators. Costs associated with the one-out-of-eight concept are considered appropriate for high-performance aircraft only, because the majority of the low-performance aircraft operate in VFR environments and utilize the 1200 code when not under ATC control. Since the system is recommended as a near-term solution, it would not be practical for VFR aircraft operators to modify their avionics for one-out-of-eight operation.

Table 7-1. SUMMARY OF SYSTEM IMPLEMENTATION AND OPERATION COSTS FOR FIRST YEAR OF OWNERSHIP (SINGLE SYSTEM PER AIRCRAFT - IN 1975 DOLLARS)

One-Out-of-Eight SAB Adapter (Retrofit Aircraft)	One-Out-of-Eight SAB Transponder (New Aircraft)	4096 SAB Adapter (Retrofit Aircraft)	4096 SAB Transponder (New Aircraft)
Commercial Aviation			
1310	7984	1995	8433
General Aviation - High-Performance Aircraft			
902	7298	1721	7838
General Aviation - Low-Performance Aircraft			
N/A	N/A	N/A	898

The 4096 SAB concept costs are presented for both the high-performance and low-performance aircraft since the implementation of this concept would result in eventual transition to a total SAB system. High-performance aircraft are expected to retrofit with SAB adapters in order to realize maximum benefit from the improved surveillance. SAB transponders would likely first appear in substantial numbers on new aircraft, with existing aircraft being refitted with SAB transponders during normal ATCRBS transponder replacement. Table 7-1 reflects this assumption in providing the first year-of-ownership costs for new aircraft in the low-performance aircraft category.

The costs presented represent the expected investment in the acquisition, installation, and operation of SAB for the first year by an aircraft owner. The results are the expected costs of implementing and operating a SAB system to permit direct comparison with the results of other studies dealing with the cost effectiveness of alternatives. Table 7-1 provides the cost of SAB implementation without regard to any ATCRBS expenditures that might be offset by the introduction of SAB. However, the true costs of SAB to the aircraft owner would be the differential increases over the cost of the present ATCRBS equipment.

APPENDIX A

SELECTIVE ADDRESS BEACON SYSTEM TIMING AND LOGIC DESIGN

This appendix provides detailed timing and logic designs for the One-out-of-Eight and the 4096 Selective Address Beacon Systems.

ONE-OUT-OF-EIGHT SAB SYSTEM TIMING AND
LOGIC DESIGNS

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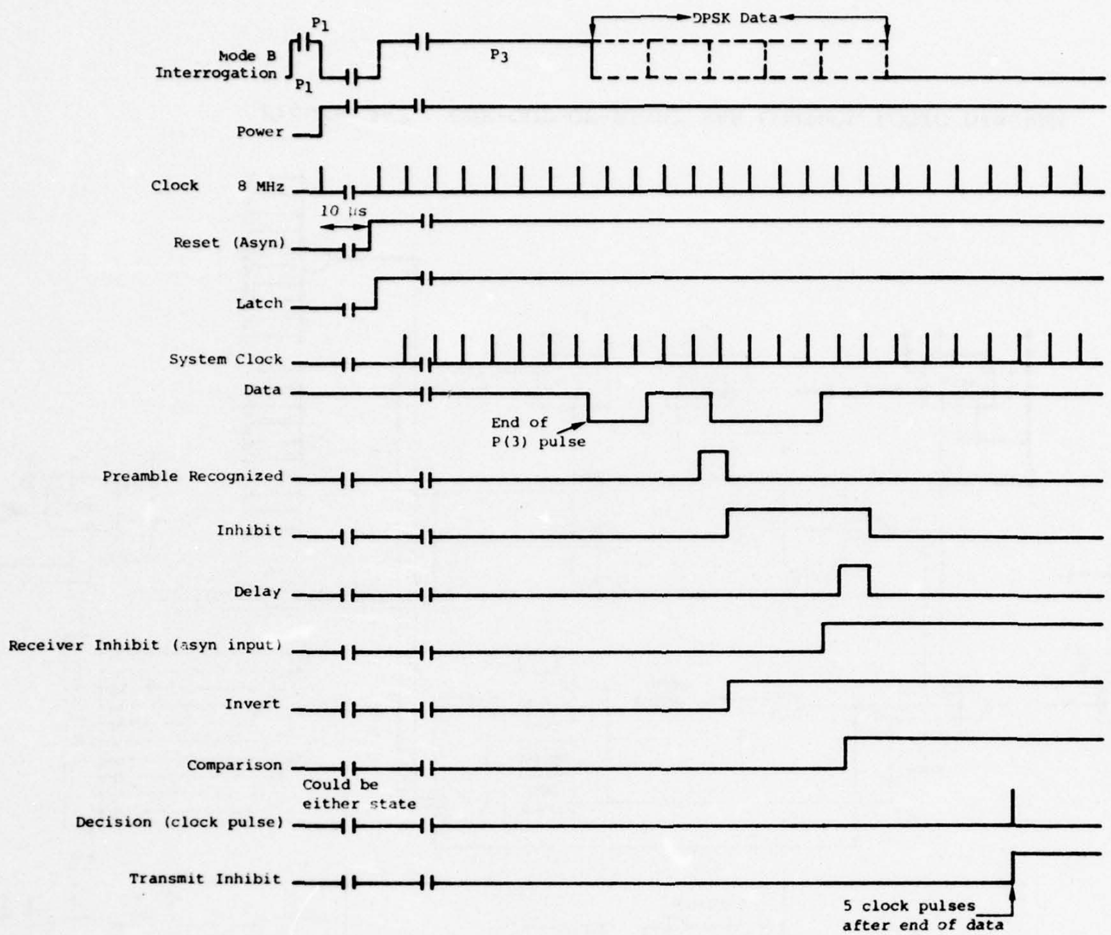

Figure A-1. ONE-OUT-OF-EIGHT SAB LOGIC TIMING CONTROL AS A FUNCTION OF GROUND INTERROGATION

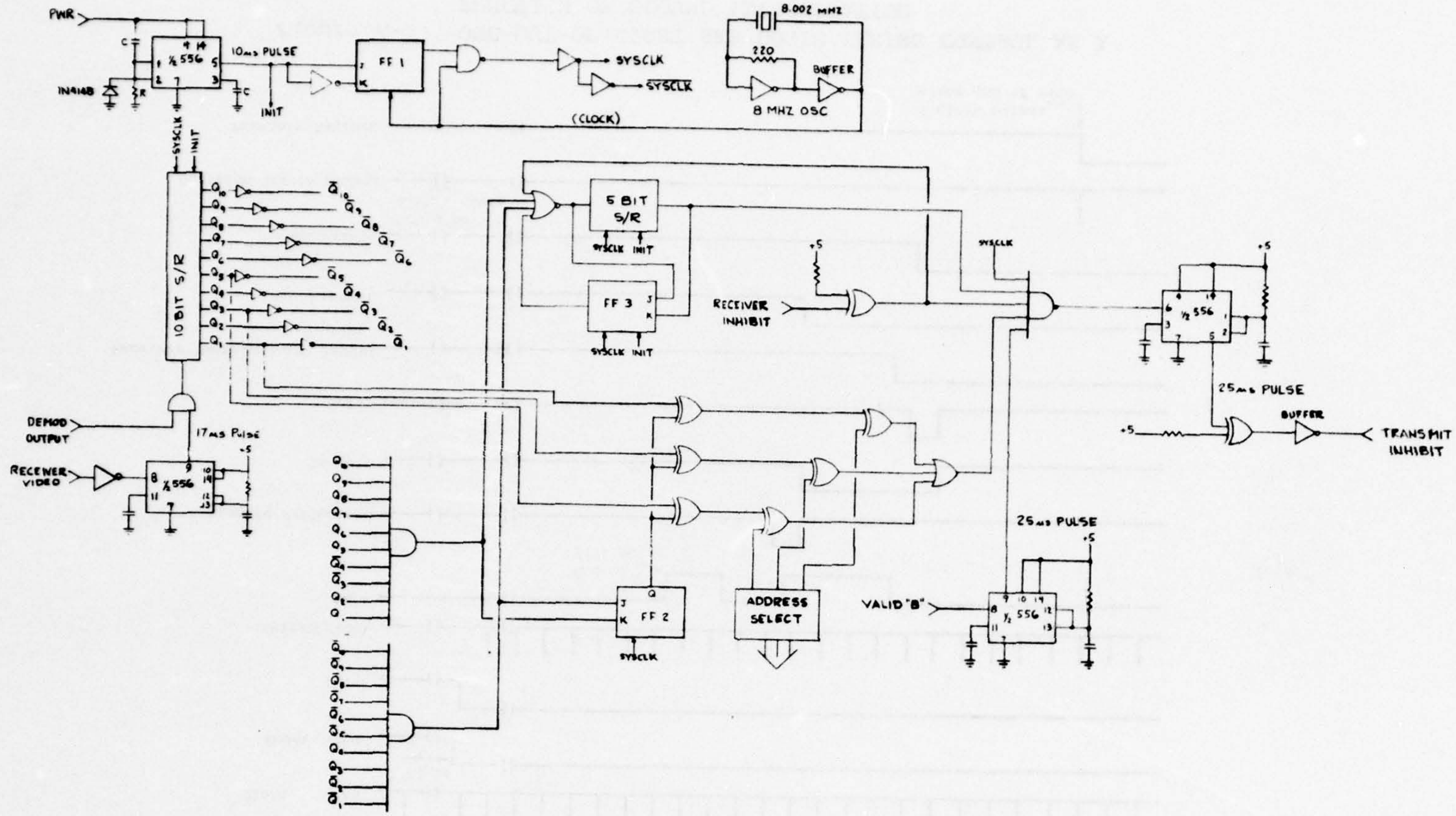

Figure A-2. ONE-OUT-OF-EIGHT SAB CONTROL LOGIC DIAGRAM

4096 SAB SYSTEM TIMING AND LOGIC DESIGNS

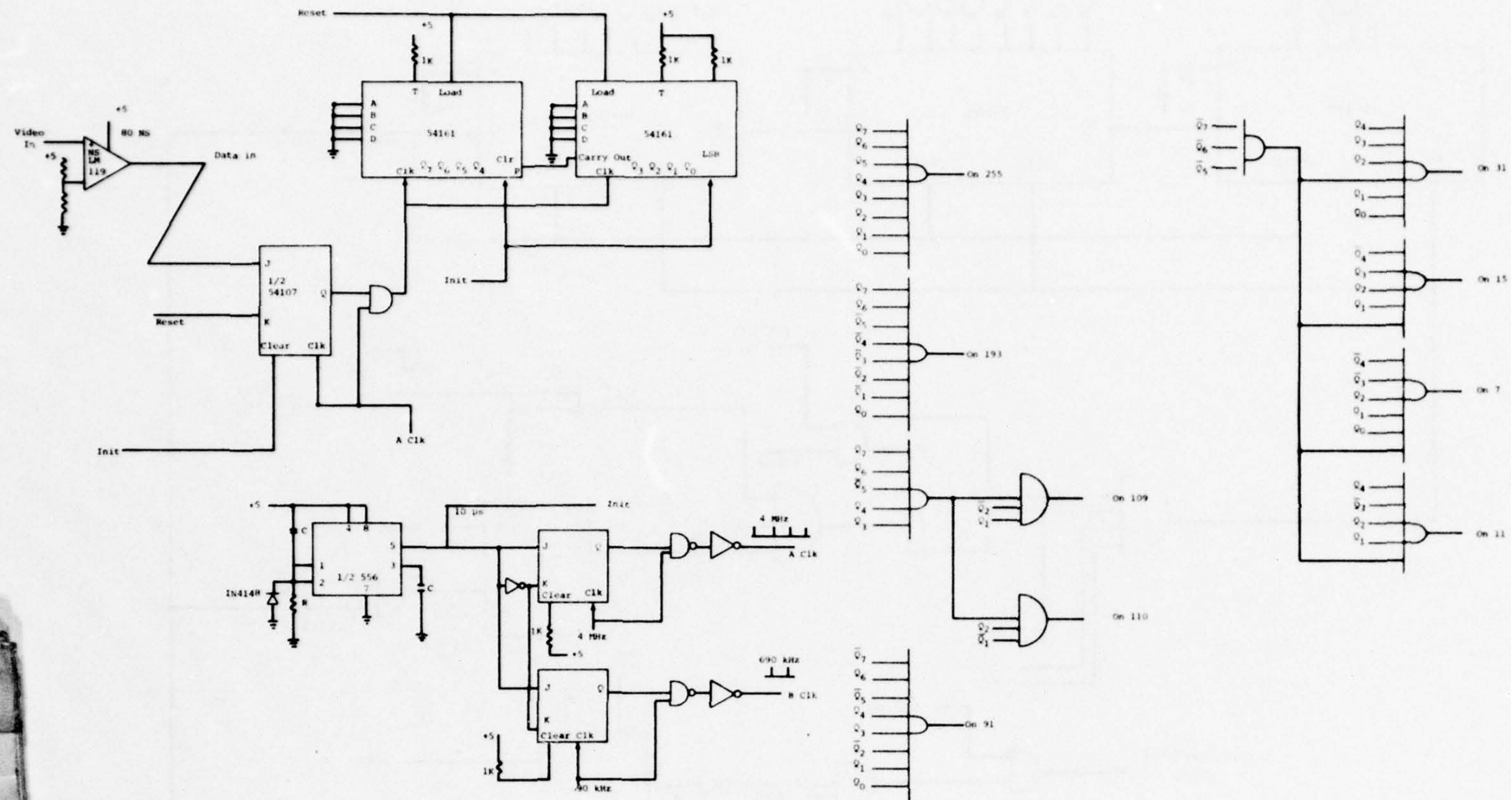

Figure A-3. 4096 SAB SYSTEM TIMING AND CONTROL

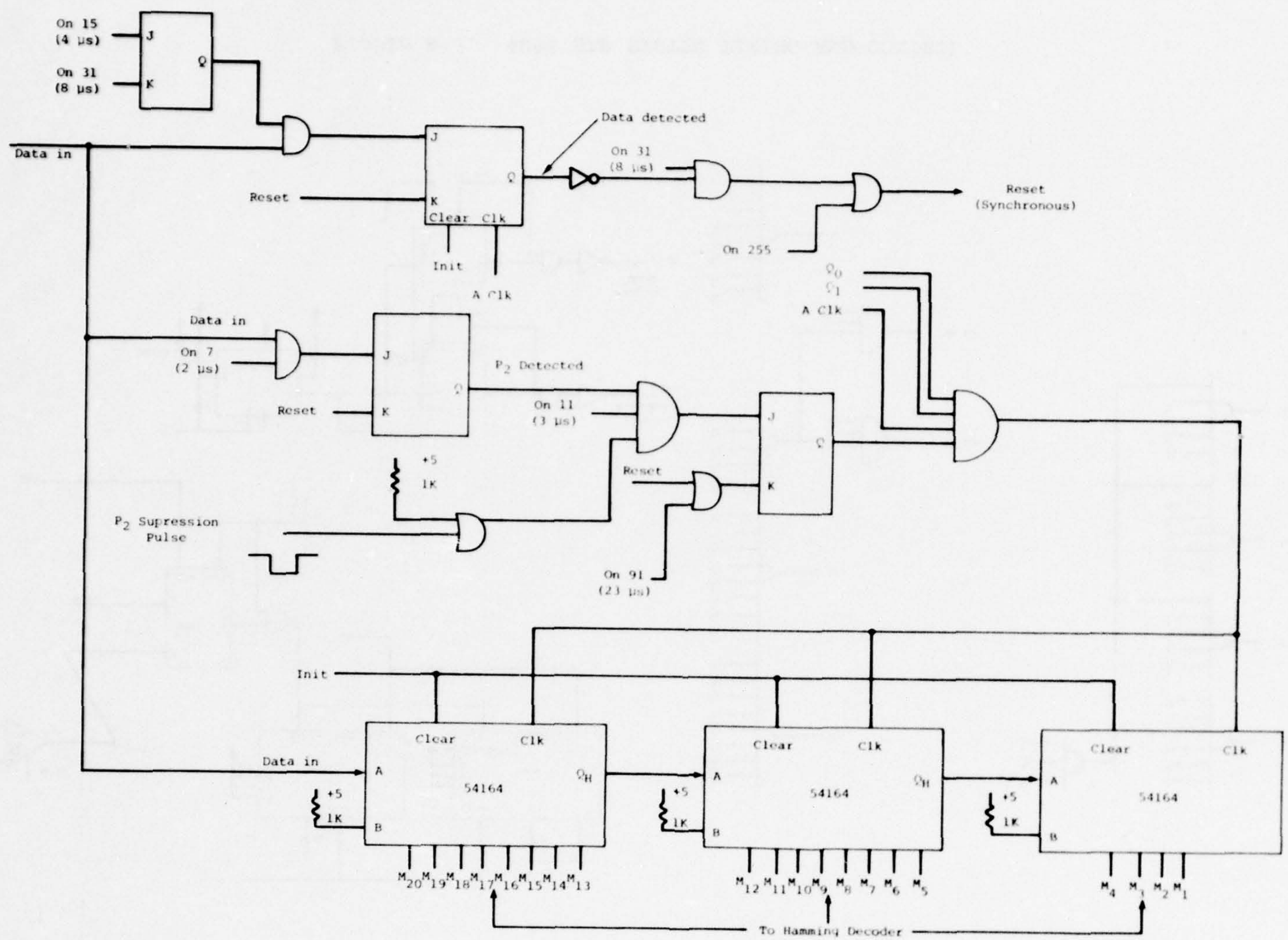

Figure A-4. 4096 SAB DATA DECODER LOGIC DIAGRAM

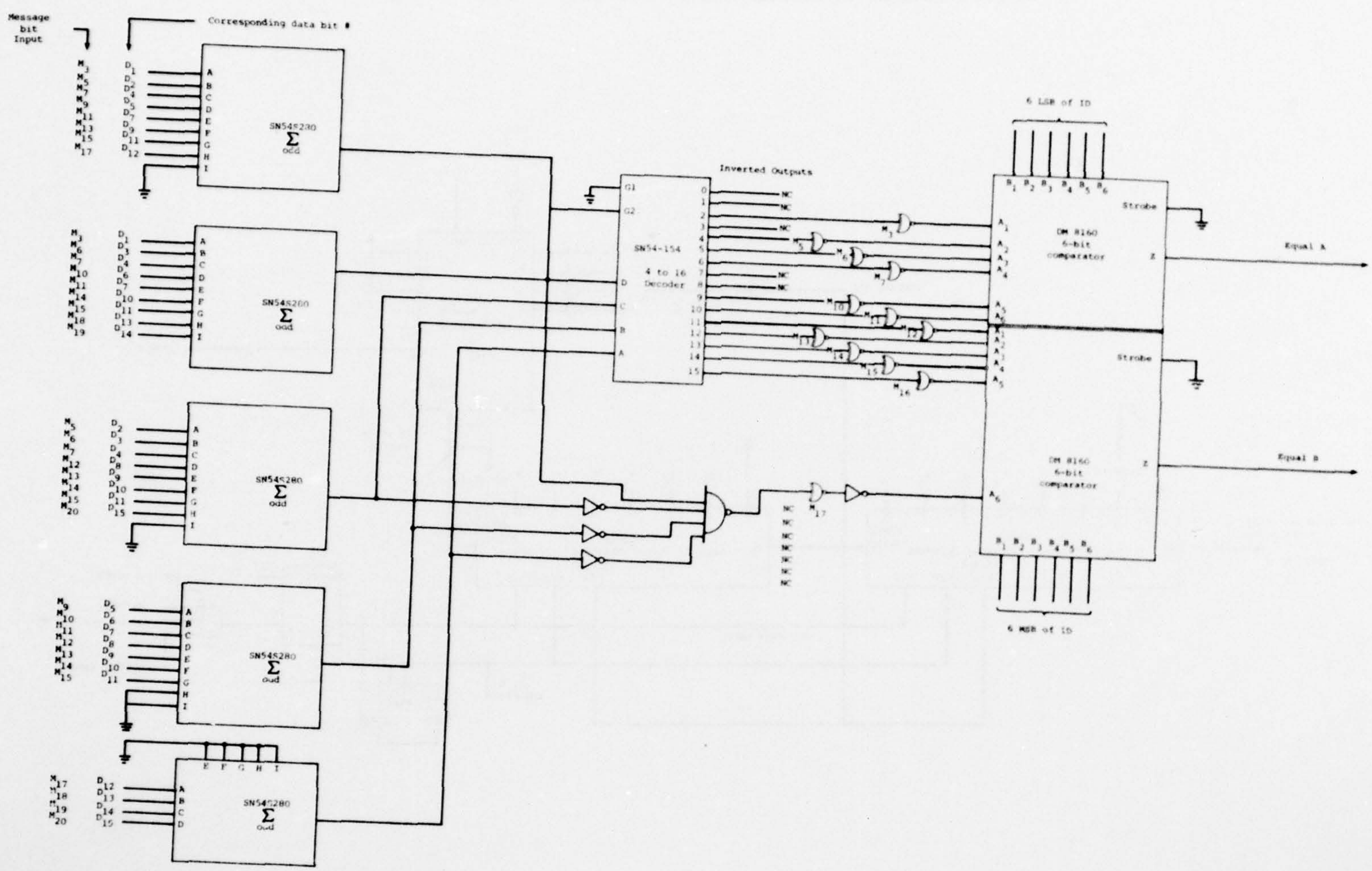

Figure A-5. 4096 SAB HAMMING DECODER LOGIC DIAGRAM

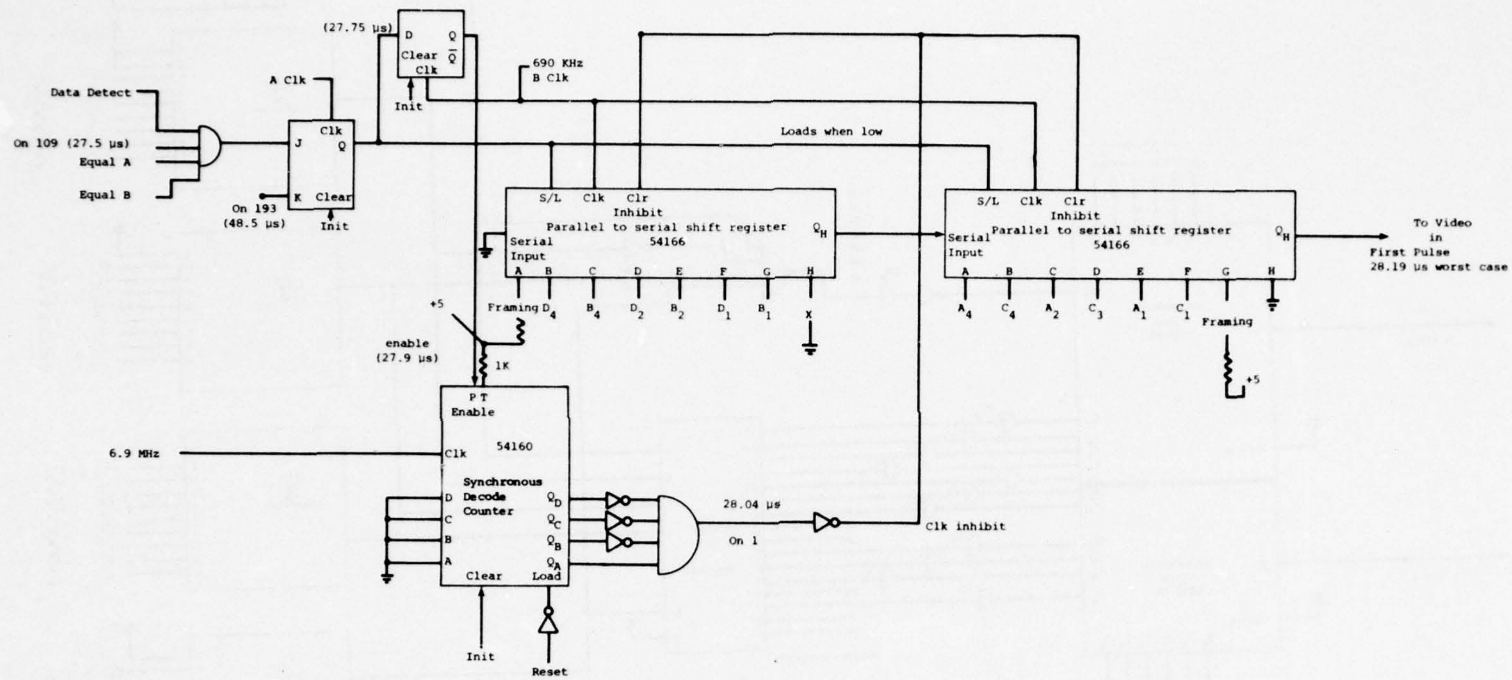

Figure A-6. 4096 SAB REPLY ENCODING LOGIC DIAGRAM

APPENDIX B

SELECTIVE ADDRESS BEACON SYSTEM MATERIAL COST AND LABOR HOURS

This appendix provides tables of detailed analysis of the material costs and labor hours associated with the production of the components of the Selective Address Beacon Systems. The tables are grouped in the following five sections:

SYSTEM One-Out-of-Eight SAB

SUB-ASSEMBLY Demodulator Card

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Saw Filter	1	4.24	4.24		8	1.18	1.18	5.003
MA 760	1	4.24	4.24		8	.715	.715	3.032
5474	1	4.45	4.45		8	.07	.07	.312
IN 758A	3	.41	1.23		15	.4	1.2	.492
IN 3666	2	1.52	3.04		10	.155	.31	.471
IN 4454	9	.13	1.17		45	.155	1.395	.186
IN 4733	1	.55	.55		5	.4	.4	.220
SD 8050	2	.50	1.00		16	2.532	5.064	2.532
Capacitor-Disc	6	.06	.36		30	.291	1.746	.105
Capacitor-Tant.	1	.18	.18		5	.55	.55	.099
Coils	6	.06	.36		30	.069	.414	.025
Resistors	13	.03	.39		65	.013	.169	.005
PC Board	1	5.00	5.00	818	20	-	-	
TOTALS			26.21	818	265x1.5 = 398		13.213	$\frac{12.482}{13.213} = .95$

SYSTEM One-Out-of-Eight SAB

SUB-ASSEMBLY Logic Decoder and Processor Card

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54H04	3	2.55	7.65		24	.18	.54	1.377
5416	1	1.33	1.33		8	.18	.18	.239
54H20	2	2.05	4.10		16	.06	.12	.246
54H73	1	5.20	5.20		8	.715	.715	3.718
54H76	1	5.50	5.50		10	.715	.715	3.933
54586	2	3.77	7.54		16	.12	.24	.905
54133	2	4.59	9.18		20	.715	.715	3.282
54164	3	3.87	11.61		24	.715	2.145	8.301
LM556	2	8.00	16.00		16	.715	1.43	11.440
IN4148	1	.13	.13		5	.155	.155	.020
Capacitor	4	.06	.24		20	.291	1.164	.070
Resistor -FC	4	.03	.12		20	.013	.052	.002
Crystal	1	2.00	2.00		15	.226	.226	.452
PC Card	1	5.00	5.00	818	20	-	-	
TOTALS			75.60	818	222x1.5 = 333		8.397	$\frac{33.985}{8.397} = 4.05$

SYSTEM One-Out-of-Eight SAB

SUB-ASSEMBLY Chassis and Test

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Chassis Frame	1							
Front Panel	1	13.78	13.78	682	168			
Cover	1							
Conn. DPAMA	1	30.00	30.00	50	25			
PC Connector	2	1.50	3.00		500			
Misc. Hardware	Lot	2.50	2.50		50			
Wiring	Lot	.25	.25		200			
Assembly					200			
Test					1000			
TOTALS			49.53	732	2143			

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SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Transmitter

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cavity Osc.	1	111.19	111.19		25	250.	250.	7250
Thermistor	2	.15	.30		10	1.35	2.7	.405
2N3723	1	7.10	7.10		6	1.266	1.266	8.989
2N4897	1	6.75	6.75		6	1.266	1.266	8.546
1N3070	3	.47	1.41		15	.155	.465	.219
IF Transformer	1	.65	.65		25	.475	.475	.309
Coils	2	.15	.30		10	.069	.138	.021
Resistor FC	11	.03	.33		55	.013	.143	.004
CAP- TANT	5	.18	.90		25	.629	3.145	.566
CAP - Disc	2	.05	.10		10	.291	.582	.029
F.T. Term.	16	.01	.16		64			
PC Board	1	5.00	5.00		10			
H.V. Module	1	44.28	44.28		250	20	20	885.6
Circulator	1	87.23	87.23		150	5	5	436.15
Board Process				485				
Cut and Swage				160				
TOTALS			265.70	645 x 2	661 x 2		285.18	$\frac{8590.8}{285.18} = 30.12$

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SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Receiver

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Preselector	1	12.50	12.50		50	1.18	1.18	14.75
Diplexer	1	110.43	110.43		100	5.00	5.00	552.15
Mixer	1	60.15	60.15		5	5.00	5.00	300.75
2N918	2	.46	.92		12	1.266	2.532	.582
2N3866	2	1.50	3.00		12	3.749	7.498	11.247
2N2369	1	.38	.38		6	1.266	1.266	.481
FD 1766	2	1.00	2.00		10	.155	.31	.31
Crystal	2	2.00	4.00		12	.266	.452	.904
Potentometer	2	3.00	6.00		30	.664	1.328	3.984
Coil, Adj.	2	.70	1.40		20	.475	.95	.666
Coil	9	.05	.45		54	.069	.621	.031
Thermistor	4	.39	1.56		20	1.35	5.4	2.106
Caps - Variable	4	1.10	4.40		60	1.58	6.32	6.952
Caps - Disc	32	.05	1.60		160	.291	9.312	.466
Resistor - FC	13	.03	.39		65	.013	.169	.005
Resistor - Film	15	.15	2.25		75	.046	.69	.104
FT Terminals	Lot	.50			100			
PC Board	2	3.00	6.00		30			
Chassis w/conn	1	12.00	12.00	388	154			
Board Process				970				
Cut & Swage				333				
TOTALS			229.93	1691 x 1.8	975 x 2		50.512	$\frac{896.069}{50.512} = 17.74$

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SYSTEM 1 of 8 SAB

SUB-ASSEMBLY IF Amplifier

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
S16835	6	.47	2.82		36	1.266	7.596	3.570
2N2907A	1	.40	.40		6	2.124	2.124	.85
2N2222	2	.40	.80		12	1.266	2.532	1.013
FH 1100	3	.33	.99		18	.155	.465	.153
HP 2800	1	.50	.50		6	.155	.155	.078
1N 755A	1	.41	.41		5	.4	.4	.164
1N 4454	1	.13	.13		5	.155	.155	.020
M760	1	4.00	4.00		8	.715	.715	2.860
Saw Filter	1	4.24	4.24		8	1.18	1.18	5.003
Potentiometer	4	3.00	12.00		60	.664	2.656	7.968
CAP - Adj.	6	1.10	6.60		90	1.58	9.48	10.428
CAP - Tant	19	.18	3.42		95	.629	11.951	2.151
DAP - Disc	44	.05	2.20		220	.291	12.804	.640
Thermistor	3	.39	1.17		15	1.35	4.05	1.580
Coil	26	.05	1.30		130	.069	1.794	.090
Resistor - FC	44	.03	1.32		220	.013	.572	.017
Resistor - Film	7	.15	1.05		35	.046	.322	.048
Conn - UG146	1	2.60	2.60		80			
PC Board	1	10.00	10.00		50			
Board Process				485				
C & S				333				
TOTALS			55.95	818	1099 x 1		58.951	$\frac{36.633}{58.951} = .62$

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SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Video Processor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MA 710	1	4.00	4.00		8	.715	.715	2.86
SG 41	2	2.05	4.10		16	.06	.12	.246
SG 81	2	3.20	6.40		16	.715	1.43	4.576
SG 141	5	2.25	11.25		40	.12	.60	1.350
SG 191	1	2.05	2.05		8	.09	.09	.185
SF 101	1	2.05	2.05		8	.715	.715	1.466
2N2222	1	.40	.40		6	1.266	1.266	.506
2N2905	1	6.00	6.00		6	2.124	2.124	12.744
2N2369	5	.40	2.00		30	1.266	6.33	2.532
2N2907A	5	.40	2.00		30	2.124	10.62	4.248
2N956	6	.74	4.44		36	1.266	2.596	5.621
2N3823	1	.78	.78		6	11.904	11.904	9.285
1N3070	2	.47	.94		10	.155	.31	.146
1N5711	6	.35	2.10		30	.155	.93	.326
1N457A	11	.35	3.85		55	.155	1.705	.597
HPA2800	4	.50	2.00		20	.155	.62	.31
1N4454	1	.13	.13		5	.155	.155	.02
Potentiometer	6	3.00	18.00		90	.664	3.985	11.952
Thermistor	3	.39	1.17		15	1.35	4.05	1.58
CAP - T/E	19	.18	3.42		95	.55	10.45	1.881
CAP - Disc	13	.05	.65		65	.291	3.783	.189
Resistor - Film	33	.15	4.95		165	.046	1.518	.228
TOTALS								

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SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Video Processor (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Resistor - FC	34	.03	1.02		170	.013	.442	.013
Misc. Hardware	Lot	5.00	5.00		100			
PC Board	1	5.00	5.00		20			
Board Process				485				
C & S				333				
TOTALS			93.70	818 x 2	1050 x 2		71.457	$\frac{62.860}{71.457}$ = .88

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SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Control Matrix

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SD 8050	23	.50	11.50		184	2.532	58.236	29.118
2N956	2	.41	.82		12	1.266	2.532	1.038
2N2907A	4	.40	1.60		24	2.124	8.496	3.398
1N4454	136	.13	17.68		680	.155	21.08	2.740
1N758A	43	.41	17.63		215	.4	17.2	7.052
1N457A	2	.35	.70		10	.155	.31	.109
1N754A	1	.41	.41		5	.4	.4	.164
1N4002	2	.12	.24		10	.155	.31	.037
54L30T	2	2.05	4.10		16	.03	.06	.123
Cap - T/E	7	.18	.126		35	.55	3.85	.693
Resistor - FC	116	.03	3.48		580	.013	1.508	.045
Resistor - Film	6	.15	.90		30	.046	.276	.041
BHGD21-65176	2	2.50	5.00		30			
MS24515-682	1	1.80	1.80		50			
PB Switch	2	.45	.90		50			
PC Board	1	5.00	5.00		20			
Board Process				485				
C & S				333				
TOTALS			73.02	818 x 2	1951 x 2		114.258	$\frac{44.558}{114.258} = .39$

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SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Monitor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54L00	4	2.05	8.20		32	.12	.48	.984
54L10	4	2.05	8.20		32	.09	.36	.738
54L20	3	2.05	6.15		24	.06	.18	.405
54L30	1	2.05	2.05		8	.03	.03	.062
54L72	1	3.15	3.15		8	.715	.715	2.252
54L73	3	5.20	15.60		24	.715	2.145	11.154
SG141	2	2.25	4.50		16	.12	.24	.540
SG81	1	3.20	3.20		8	.715	.715	2.288
SG191	1	2.05	2.05		8	.09	.09	.185
SD8050	2	.50	1.00		16	2.532	5.064	2.532
MA710	2	4.00	8.00		16	.715	1.43	5.72
2N2907A	3	.40	1.20		18	2.124	6.372	2.549
2N2646	3	.67	2.01		18	1.266	3.798	2.545
2N887	2	.50	1.00		12	1.58	3.16	1.580
2N2369	1	.38	.38		6	1.266	1.266	.481
2N956	1	.41	.41		6	1.266	1.266	.519
1N746A	1	.49	.49		5	.4	.4	.196
1N4002	1	.12	.12		5	.155	1.705	.019
1N4454	11	.13	1.43		55	.155	1.705	.222
Potentiometer	2	3.00	6.00		30	.664	1.328	3.984
Coil	1	.05	.05		5	.069	.069	.003
Cap - T/E	9	.18	1.62		45	.55	4.95	.891
TOTALS								

SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Monitor (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cap - Disc	6	.05	.30		30	.291	1.746	.087
Resistor - Film	16	.15	2.40		80	.046	.736	.110
Resistor - FC	25	.03	.75		125	.013	.325	.010
Connector	1	1.50	1.50		25			
PC Board	1	5.00	5.00	818	20			
TOTALS			86.76	818 x 2	2102 x 2		38.725	$\frac{40.055}{38.725} = 1.03$

SHEET 9 OF 16

SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Power Supply

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N2905A	2	.61	1.22		12	2.498	4.996	3.048
2N3054	1	.82	.82		6	3.749	3.749	3.074
2N1613	4	.60	2.40		24	1.266	5.064	3.038
2N3740	2	1.20	2.40		12	2.498	4.996	5.995
2N3055	1	1.05	1.05		6	3.749	3.749	3.939
1N4002	9	.12	1.08		45	.155	1.395	.167
1N4740	1	.38	.38		5	.4	.4	.152
1N4736A	2	.41	.82		10	.4	.8	.328
1N4734A	2	.41	.82		10	.8	.8	.328
1N4719	2	.35	.70		10	.358	.716	.251
1N754	2	.60	1.20		10	.4	.8	.480
1N4562B	1	5.65	5.65		5	.4	.4	2.260
1N4735A	1	1.40	1.40		5	.4	.4	.560
1N4005	1	.42	.42		5	.361	.361	.152
1N4454	1	.13	.13		5	.155	.155	.020
Transformer	1	11.00	11.00		615	1.5	1.5	16.50
3jX37B	2	.75	.75		50	.651	1.302	.977
Potentiometer	3	3.00	9.00		45	.664	1.992	5.976
Cap - T/E	15	.18	2.70		75	.55	8.25	1.485
Cap - Disc	2	.05	.10		10	.291	.582	.029
Resistor-Film	14	.15	2.10		70	.046	.644	.097
Resistor - FC	12	.03	.36		60	.013	.156	.005
TOTALS								

[illegible] (Cont'd)

[illegible]	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
[illegible]	2	.37	.74		20			
[illegible]	1	5.00	5.00		10			
[illegible]	Lot	2.00	2.00		100			
[illegible]				485				
[illegible]				333				
TOTALS			54.24	818	1225 x 1		43.207	$\frac{48.857}{43.207} = 1.13$

SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Logic Decoder Card

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SF 101	2	2.05	4.10		16	.715	1.43	2.932
SF 51	1	2.05	2.05		8	.715	.715	1.466
SG 81	1	3.20	3.20		8	.715	.715	2.288
SG 130	1	2.25	2.25		8	.06	.06	.135
SG 141	2	2.25	4.50		16	.12	.24	.540
SG 191	1	2.05	2.05		8	.09	.09	.185
54L00	1	2.05	2.05		8	.12	.12	.246
54H04	1	2.55	2.55		8	.035	.035	.089
54L10	2	2.05	4.10		16	.09	.18	.369
54L20	3	2.05	6.15		24	.24	.72	1.476
54L54	2	2.05	4.10		16	.175	.350	.718
54L73	5	5.20	26.00		40	.715	3.575	18.590
54H76	1	5.50	5.50		10	.715	.715	3.933
54164	2	3.87	7.74		16	.715	1.43	5.534
LM 556	1	8.00	8.00		10	.715	.715	5.720
S16835	1	.47	.47		6	1.266	1.266	.595
Crystal	2	2.00	4.00		30	.266	.532	1.064
Coil	1	.06	.06		5	.069	.069	.004
Resistor(Film)	9	.15	1.35		45	.013	.117	.018
Capacitor-Disc	5	.06	.30		25	.291	1.455	.087
Capacitor-TANT	4	.18	.72		20	.55	2.2	.396
2N2369	1	.38	.38		6	1.266	1.266	.481
TOTALS								

SHEET 12 OF 16

SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Logic Decoder Card (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Test Points	10	.06	.60		50	-		
PC Board	1	5.00	5.00		25	-		
Board Process	1	-	-	485		-		
C & S	1	-	-	333		-		
TOTALS			97.22	818	424 x 2 = 848		22.843	$\frac{46.866}{22.843} = 2.05$

SHEET 13 OF 16

SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Logic Encoder Card

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SF 101	4	2.05	8.20		32	.715	2.86	5.863
SF 51	1	2.05	2.05		8	.715	.715	1.466
SG 41	2	2.05	4.10		16	.06	.12	.246
SG 130	1	2.25	2.25		8	.06	.06	.135
SG 141	2	2.25	4.50		16	.12	.24	.540
SG 191	2	2.05	4.10		16	.09	.18	.369
54L00	1	2.05	2.05		8	.12	.12	.246
54H04	1	2.55	2.55		8	.035	.035	.089
54L10	2	2.05	4.10		16	.09	.18	.369
5416	1	1.33	1.33		8	.18	.18	.239
54L20	2	2.05	4.10		16	.24	.48	.984
54H30	1	2.05	2.05		8	.03	.03	.063
54H73	1	5.20	5.20		8	.715	.715	3.718
54L73	4	5.20	20.80		8	.715	2.86	14.872
54S86	2	3.77	7.54		16	.12	.24	.905
54164	1	3.87	3.87		8	.715	.715	2.767
LM556	1	8.00	8.00		10	.715	.715	5.720
S16835	1	.47	.47		6	1.266	1.266	.595
2N2369	1	.38	.38		6	1.266	1.266	.481
Crystal	1	2.00	2.00		15	.266	.266	.532
Coil	1	.06	.06		5	.069	.069	.004
Resistor (Film)	6	.15	.90		30	.013	.078	.012
TOTALS								

SHEET 14 OF 16

SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Logic Encoder Card (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Capacitor-Disc	7	.06	.42		35	.291	2.037	.122
Capacitor-TANT	1	.18	.18		5	.55	.55	.099
Test Points	10	.06	.60		50	-	-	-
PC Board	1	5.00	5.00		25	-	-	-
Board Process	1	-	-	485	-	-	-	-
C & S	1	-	-	333	-	-	-	-
TOTALS			96.80	818	387 x 2 = 774		15.977	$\frac{40.435}{15.977} = 2.53$

SHEET 15 OF 16

SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Chassis

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cable Assy	1				1000.			
Conn, Plug	2	2.50	5.00		50	1.342	2.684	6.710
Chassis Assy	1							
Front Panel	1	13.00	13.00	1365	684			
RF Cables	Lot							
RF Conn.	5	(1.25)				1.128	5.64	7.050
Misc. Hardware	Lot							
Conn. ARINC	2	40.00	80.00		1000.	1.342	2.684	107.360
PC Conn.					500			
Wiring	Lot					6.3		
TOTALS			98.00	1365.	3234.		17.308	$\frac{121.120}{17.308} = 7.00$

SHEET 16 OF 16

SYSTEM 1 of 8 SAB

SUB-ASSEMBLY Final Assembly

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Transmitter	1				60			
Receiver	1				50			
IF Amplifier	1				50			
Video Proc.	1				50			
Control Matrix	1				50			
Monitor	1				75			
Power Supply	1				190			
Encoder	1				50			
Decoder	1				50			
Chassis	1				150			
Func. Test					2000			
Burn-In					1000			
TOTALS					3775			

SHEET 1 OF 5

SYSTEM 4096 SAB Adapter

SUB-ASSEMBLY Comparator-Control-Clocks

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5400	1	.85	.85		8	.12	.12	.102
5404	1	1.06	1.06		8	.21	.21	.223
5408	1	.85	.85		8	.14	.14	.119
5411	1	1.09	1.09		8	.105	.105	.114
54107	2	1.33	2.66		16	.715	1.43	1.902
54S133	7	4.59	32.13		70	.715	5.005	22.973
54161	2	2.83	5.66		20	.715	1.43	4.047
555	1	4.50	4.50		8	.715	.715	3.218
LM119	1	19.50	19.50		10	.715	.715	13.943
2N956	1	.65	.65		6	1.266	1.266	.823
1N4148	1	.13	.13		5	.155	.155	.020
Capacitor-Tant	3	.18	.54		15	.55	1.65	.297
Capacitor-Disc.	3	.06	.18		15	.291	.873	.052
Resistor	11	.03	.33		55	.013	.143	.004
PC Board	1	5.00	5.00		25	-	-	-
Board Process	1	-	-	485	-	-	-	-
C&S	1	-	-	333	-	-	-	-
TOTALS			75.13	818	277 x 1.5 = 416		13.957	$\frac{47.837}{13.957} = 3.43$

SYSTEM 4096 SAB Adapter

SUB-ASSEMBLY Data Decode and Early Reset

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5404	1	1.06	1.06		8	.21	.21	.223
5408	1	.85	.85		8	.14	.14	.119
5411	1	1.09	1.09		8	.105	.105	.114
5420	1	.85	.85		8	.24	.24	.204
54H21	1	2.05	2.05		8	.07	.07	.144
5432	1	1.15	1.15		8	.12	.12	.138
54107	2	1.33	2.66		16	.715	1.43	1.902
54154	1	5.35	5.35		12	.715	.715	3.825
54164	3	3.87	11.61		24	.715	2.145	8.301
54S280	5	19.43	97.15		40	.715	3.755	72.960
DM8160	2	3.20	6.40		20	.715	1.43	4.576
9386	3	1.61	4.83		24	.715	2.145	3.453
Resistors	3	.03	.09		15	.013	.039	.001
PC Board	1	5.00	5.00		25	-	-	-
Board Process	1	-	-	485	-	-	-	-
C&S	1	-	-	333	-	-	-	-
TOTALS			140.14	818	224 x 1.7 = 381		12.544	$\frac{95.960}{12.544} = 7.65$

SHEET 3 OF 5

SYSTEM 4096 SAB Adapter

SUB-ASSEMBLY Encoder and Control Matrix

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5404	1	1.06	1.06		8	.21	.21	.223
54H21	1	2.05	2.05		8	.07	.07	.144
54107	1	1.33	1.33		8	.715	.715	.951
54160	1	3.02	3.02		10	.715	.715	2.159
54166	2	7.38	14.76		20	.715	1.43	10.553
SD8050	13	.50	6.50		104	4.332	56.319	28.160
IN758A	24	.40	9.60		120	.4	9.6	3.840
IN4454	74	.13	9.62		370	.155	11.47	1.491
Resistors	77	.03	2.31		385	.013	1.001	.030
PC Board	1	5.00	5.00		25	-	-	-
Board Process	1	-	-	485	-	-	-	-
C&S	1	-	-	333	-	-	-	-
TOTALS			55.25	818	1058 x 1.4 = 1481		81.530	$\frac{47.551}{81.530} = 0.58$

SYSTEM 4096 SAB Adapter

SUB-ASSEMBLY Power Supply

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N3740	1	1.10	1.10		6	2.498	2.498	2.748
2N3055	1	.90	.90		6	3.749	3.749	3.374
2N1613	2	.60	1.20		12	1.266	2.532	1.519
1N754	1	.40	.40		5	.4	.4	.160
IN4002	2	.12	.24		10	.155	.31	.037
IN4562B	1	8.65	8.65		5	.4	.4	3.460
IN4719	2	.69	1.38		10	.155	.31	.214
Capacitor-T	6	.18	1.08		30	.55	3.3	.594
Potentiometer	1	3.00	3.00		15	.664	.664	1.992
Filter	2	1.50	3.00		50	.651	1.302	1.953
Fuse and Holder	1	.65	.65		25	-	-	-
PC Board	1	3.00	3.00		25	-	-	-
Board Process	1	-	-	485		-	-	-
C&S	1	-	-	333		-	-	-
TOTALS			24.60	818	199 x 1.4 = 279		15.465	$\frac{16.051}{15.465} = 1.04$

SHEET 5 OF 5

SYSTEM 4096 SAB Adapter

SUB-ASSEMBLY Chassis and Final Assembly

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Transformer	1	4.50	4.50		315	1.5	1.5	6.75
Chassis	1	7.00	7.00	184	44	-	-	-
Front Plate	1	3.00	3.00	74	22	-	-	-
Cover	1	3.00	3.00	124	44	-	-	-
DPX Connector	1	11.97	11.97		50	1.342	1.342	16.064
PC Connector	4	1.67	6.68		60	-	-	-
Wiring	Lot	.75	.75		300	2.1	2.1	1.575
Misc. Hardware	Lot	3.50	3.50		250	-	-	-
Functional Test	-	-	-		2000	-	-	-
Burn-In	-	-	-		1000	-	-	-
TOTALS			40.40	382	3985		4.942	$\frac{24.389}{4.942} = 4.94$

SYSTEM 4096 SAB

SUB-ASSEMBLY Transmitter

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cavity Osc.	1	111.19	111.19		25	250.	250.	7250.
Thermistor	2	.15	.30		10	1.35	2.7	.405
2N3723	1	7.10	7.10		6	1.266	1.266	8.989
2N4897	1	6.75	6.75		6	1.266	1.266	8.546
1N3070	3	.47	1.41		15	.155	.465	.219
IF Transformer	1	.65	.65		25	.475	.475	.309
Coils	2	.15	.30		10	.069	.138	.021
Resistor FC	11	.03	.33		55	.013	.143	.004
CAP - Tant.	5	.18	.90		25	.629	3.145	.566
CAP - Disc	2	.05	.10		10	.291	.582	.029
F.T. Term.	16	.02	.16		64			
PC Board	1	5.00	5.00		10			
H.V. Module	1	44.28	44.28		250	20.	20.	885.6
Circulator	1	87.23	87.23		150	5.	5.	436.15
Board Process				485				
Cut and Swage				160				
TOTALS			265.70	645 x 2	661 x 2		285.18	$\frac{8590.8}{285.18} = 30.12$

SYSTEM 4096 SAB

SUB-ASSEMBLY Receiver

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Preselector	1	12.50	12.50		50	1.18	1.18	14.75
Diplexer	1	110.43	110.43		100	5.00	5.00	552.15
Mixer	1	60.15	60.15		5	5.00	5.00	300.75
2N918	2	.46	.92		12	1.266	2.532	.582
2N3866	2	1.50	3.00		12	3.749	7.498	11.247
2N2369	1	.38	.38		6	1.266	1.266	.481
FD 1766	2	1.00	2.00		10	.155	.31	.31
Crystal	2	2.00	4.00		12	.266	.452	.904
Potentometer	2	3.00	6.00		30	.664	1.328	3.984
Coil, Adj.	2	.70	1.40		20	.475	.95	.666
Coil	9	.05	.45		54	.069	.621	.031
Thermistor	4	.39	1.56		20	1.35	5.4	2.106
Caps - Variable	4	1.10	4.40		60	1.58	6.32	6.952
Caps - Disc	32	.05	1.60		160	.291	9.312	.466
Resistor - FC	13	.03	.39		65	.013	.169	.005
Resistor -Film	15	.15	2.25		75	.046	.69	.104
FT Terminals	Lot	.50	.50		100			
PC Board	2	3.00	6.00		30			
Chassis w/conn	1	12.00	12.00	388	154			
Board Process				970				
Cut and Swage				333				
TOTALS			229.93	1691 x 1.8	975 x 2		50.512	$\frac{896.069}{50.512} = 17.74$

AD-A058 457 ARINC RESEARCH CORP ANNAPOLIS MD F/G 17/7
DEVELOPMENT AND EVALUATION OF SELECTIVE ADDRESS BEACON (SAB) SY--ETC(U)
AUG 78 S H KOWALSKI DOT-FA76WA-3788
UNCLASSIFIED 1326-11-2-1734 NL

2 OF 2
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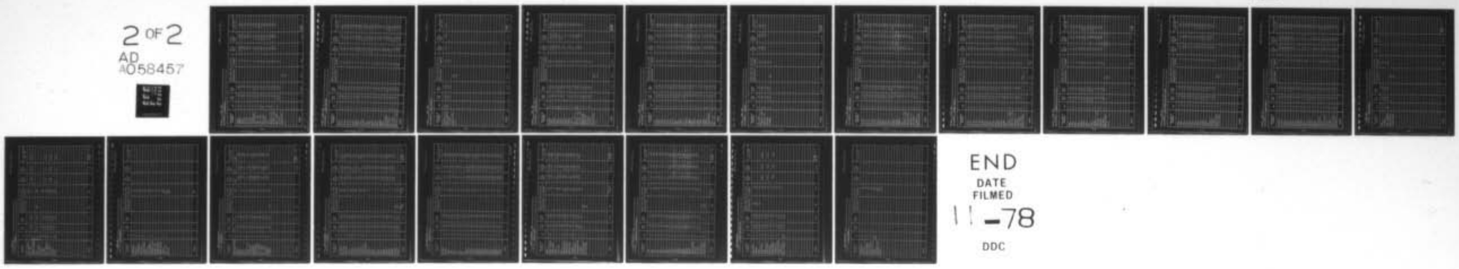

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SYSTEM 4096 SAB

SUB-ASSEMBLY IF Amplifier

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
S16835	6	.47	2.82		36	1.266	7.596	3.570
2N2907A	1	.40	.40		6	2.124	2.124	.85
2N2222	2	.40	.80		12	1.266	2.532	1.013
FH 1100	3	.33	.99		18	.155	.465	.153
HP 2800	1	.50	.50		6	.155	.155	.078
1N 755A	1	.41	.41		5	.4	.4	.164
Potentiometer	4	3.00	12.00		60	.664	2.656	7.968
CAP - Adj.	6	1.10	6.60		90	1.58	9.48	10.428
CAP - Tant	19	.18	3.42		95	.629	11.951	2.151
DAP - Disc	44	.05	2.20		220	.291	12.804	.640
Thermistor	3	.39	1.17		15	1.35	4.05	1.580
Coil	20	.05	1.00		100	.069	1.380	.069
Resistor - FC	40	.03	1.20		200	.013	.520	.016
Resistor -Film	7	.15	1.05		35	.046	.322	.048
Conn - UG146	1	2.60	2.60		80			
PC Board	1	10.00	10.00		50			
Board Process				485				
C & S				333				
TOTALS			47.16	818	1028		56.435	$\frac{28.728}{56.435} = .51$

SYSTEM 4096 SAB

SUB-ASSEMBLY Video Processor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MA 710	1	4.00	4.00		8	.715	.715	2.86
SG 41	2	2.05	4.10		16	.06	.12	.246
SG 81	2	3.20	6.40		16	.715	1.43	4.576
SG 141	5	2.25	11.25		40	.12	.60	1.350
SG 191	1	2.05	2.05		8	.09	.09	.185
SF 101	1	2.05	2.05		8	.715	.715	1.466
2N2222	1	.40	.40		6	1.266	1.266	.506
2N2905	1	6.00	6.00		6	2.124	2.124	12.744
2N2369	5	.40	2.00		30	1.266	6.33	2.532
2N2907A	5	.40	2.00		30	2.124	10.62	4.248
2N956	6	.74	4.44		36	1.266	2.596	5.621
2N3823	1	.78	.78		6	11.904	11.904	9.285
1N3070	2	.47	.94		10	.155	.31	.146
1N5711	6	.35	2.10		30	.155	.93	.326
1N457A	11	.35	3.85		55	.155	1.705	.597
HPA2800	4	.50	2.00		20	.155	.62	.31
1N4454	1	.13	.13		5	.155	.155	.02
Potentiometer	6	3.00	18.00		90	.664	3.985	11.952
Thermistor	3	.39	1.17		15	1.35	4.05	1.58
CAP - T/E	19	.18	3.42		95	.55	10.45	1.881
CAP - Disc	13	.05	.65		65	.291	3.783	.189
Resistor - Film	33	.15	4.95		165	.046	1.518	.228
TOTALS								

SYSTEM 4096 SAB

SUB-ASSEMBLY Video Processor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Resistor - FC	34	.03	1.02		170	.013	.442	.013
Misc. Hardware	Lot	5.00	5.00		100			
PC Board	1	5.00	5.00		20			
Board Process				485				
C & S				333				
TOTALS			93.70	818 x 2	1050 x 2		71.457	$\frac{62.860}{71.457} = .88$

SYSTEM 4096 SAB

SUB-ASSEMBLY Control Matrix

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SD 8050	23	.50	11.50		184	2.532	58.236	29.118
2N956	2	.41	.82		12	1.266	2.532	1.038
2N2907A	4	.40	1.60		24	2.124	8.496	3.398
1N4454	136	.13	17.68		680	.155	21.08	2.740
1N758A	43	.41	17.63		215	.4	17.2	7.052
1N457A	2	.35	.70		10	.155	.31	.109
1N754A	1	[illegible]	.41		5	.4	.4	.164
1N4002	2	.12	.24		10	.155	.31	.037
54L30T	2	2.05	4.10		16	.03	.06	.123
Cap - T/E	7	.18	.126		35	.55	3.85	.693
Resistor - FC	116	.03	3.48		580	.013	1.508	.045
Resistor - Film	6	.15	.90		30	.046	.276	.041
BHGD21-65176	2	2.50	5.00		30			
MS24515-682	1	1.80	1.80		50			
PB Switch	2	.45	.90		50			
PC Board	1	5.00	5.00		20			
Board Process				485				
C & S				333				
TOTALS			73.02	818 x 2	1951 x 2		114.258	$\frac{44.558}{114.258} = .39$

SHEET 7 OF 16

SYSTEM 4096 SAB

SUB-ASSEMBLY Monitor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54L00	4	2.05	8.20		32	.12	.48	.984
54L10	4	2.05	8.20		32	.09	.36	.738
54L20	3	2.05	6.15		24	.06	.18	.405
54L30	1	2.05	2.05		8	.03	.03	.062
54L72	1	3.15	3.15		8	.715	.715	2.252
54L73	3	5.20	15.60		24	.715	2.145	11.154
SG 141	2	2.25	4.50		16	.12	.24	.540
SG81·	1	3.20	3.20		8	.715	.715	2.288
SG191	1	2.05	2.05		8	.09	.09	.185
SD8050	2	.50	1.00		16	2.532	5.064	2.532
MA710	2	4.00	8.00		16	.715	1.43	5.72
2N2907A	3	.40	1.20		18	2.124	6.372	2.549
2N2646	3	.67	2.01		18	1.266	3.798	2.545
2N887	2	.50	1.00		12	1.58	3.16	1.580
2N2369	1	.38	.38		6	1.266	1.266	.481
2N956	1	.41	.41		6	1.266	1.266	.519
1N746A	1	.49	.49		5	.4	.4	.196
1N4002	1	.12	.12		5	.155	1.705	.019
1N4454	11	.13	1.43		55	.155	1.705	.222
Potentiometer	2	3.00	6.00		30	.664	1.328	3.984
Coil	1	.05	.05		5	.069	.069	.003
Cap - T/E	9	.18	1.62		45	.55	4.95	.891
TOTALS								

SHEET 8 OF 16

SYSTEM 4096 SAB

SUB-ASSEMBLY Monitor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cap - Disc	6	.05	.30		30	.291	1.746	.087
Resistor - Film	16	.15	2.40		80	.046	.736	.110
Resistor - FC	25	.03	.75		125	.013	.325	.010
Connector	1	1.50	1.50		25			
PC Board	1	5.00	5.00	818	20			
TOTALS			86.76	818 x 2	2102 x 2		38.725	$\frac{40.055}{38.725} = 1.03$

SYSTEM 4096 SAB

SUB-ASSEMBLY ATCRBS Decoder

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SF 101	2	2.05	4.10		16	.715	1.430	2.932
SF 51	1	2.05	2.05		8	.715	.715	1.466
SG 81	1	3.20	3.20		8	.715	.715	2.288
SG 130	1	2.25	2.25		8	.06	.06	.135
SG 141	2	2.25	4.50		16	.12	.24	.540
SG 191	1	2.05	2.05		8	.09	.09	.369
54L00	1	2.05	2.05		8	.12	.12	.246
54L10	2	2.05	4.10		16	.09	.18	.369
54L20	3	2.05	6.15		24	.24	.72	1.476
54L54	2	2.05	4.10		16	.175	.35	.718
54L73	5	5.20	26.00		40	.715	3.575	18.590
S16835	1	.47	.47		6	1.266	1.266	.595
2N2369	1	.38	.38		6	1.266	1.266	.481
Crystal	1	2.00	2.00		15	.266	.266	.532
Coil	1	.06	.06		5	.069	.069	.004
Resistor - Film	6	.15	.90		30	.013	.078	.012
Capacitor-Disc	3	.06	.18		15	.291	.873	.052
Capacitor - T	4	.18	.72		20	.55	2.200	.396
Test Points	10	.06	.60		50	-	-	-
PC Board	1	5.00	5.00		25	-	-	-
Board Process	1	-	-	818	-	-	-	-
TOTALS			70.86	818	340 x 2 = 680		14.213	$\frac{31.201}{14.213}$ = 2.20

SYSTEM 4096 SAB

SUB-ASSEMBLY ATCRBS Encoder

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SF 101	4	2.05	8.20		32	.715	2.860	5.863
SF 51	1	2.05	2.05		8	.715	.715	1.466
SG 41	2	2.05	4.10		16	.06	.12	.246
SG 130	1	2.25	2.25		8	.06	.06	.135
SG 141	2	2.25	4.50		16	.12	.24	.540
SG 191	2	2.05	4.10		16	.09	.18	.369
54L00	1	2.05	2.05		8	.12	.12	.246
54L10	1	2.05	2.05		8	.035	.035	.072
54L20	2	2.05	4.10		16	.09	.18	.369
54L54	2	2.05	4.10		16	.24	.48	.984
54L73	4	5.20	20.80		32	.715	2.860	14.872
S16835	1	.47	.47		6	1.266	1.266	.595
2N2369	1	.38	.38		6	1.266	1.266	.481
Crystal	1	2.00	2.00		15	.266	.266	.532
Coil	1	.06	.06		5	.069	.069	.004
Resistor - Film	4	.15	.60		20	.013	.052	.008
Capacitor - Disc	3	.06	.18		15	.291	.873	.052
Capacitor - T	1	.18	.18		5	.55	.55	.099
PC Board	1	5.00	5.00		25	-	-	
Test Points	10	.06	.60		50	-	-	
Board Process	1	-	-	818				
TOTALS			67.77	818	323 x 2 = 646		12.192	$\frac{26.933}{12.192} = 2.21$

SYSTEM 4096 SAB

SUB-ASSEMBLY Comparator-Control-Clocks

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5400	1	.85	.85		8	.12	.12	.102
5404	1	1.06	1.06		8	.21	.21	.223
5408	1	.85	.85		8	.14	.14	.119
5411	1	1.09	1.09		8	.105	.105	.114
54107	2	1.33	2.66		16	.715	1.43	1.902
54S133	7	4.59	32.13		70	.715	5.005	22.973
54161	2	2.83	5.66		20	.715	1.43	4.047
555	1	4.50	4.50		8	.715	.715	3.218
LM119	1	19.50	19.50		10	.715	.715	13.943
1N4148	1	.13	.13		5	.155	.155	.020
Capacitor - Disc	2	.06	.12		10	.291	.582	.035
Resistor	8	.03	.24		40	.013	.104	.003
PC Board	1	5.00	5.00		25	-		
Board Process	1	-	-	485	-	-		
C & S	1	-	-	333				
TOTALS			73.79	818	236 x 1.5 = 354		10.711	$\frac{46.699}{10.711} = 4.36$

SYSTEM 4096 SAB

SUB-ASSEMBLY Data Decode and Early Reset

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5404	1	1.06	1.06		8	.21	.21	.223
5408	1	.85	.85		8	.14	.14	.119
5411	1	1.09	1.09		8	.105	.105	.114
5420	1	.85	.85		8	.24	.24	.204
54H21	1	2.05	2.05		8	.07	.07	.144
5432	1	1.15	1.15		8	.12	.12	.138
54107	2	1.33	2.66		16	.715	1.43	1.902
54154	1	5.35	5.35		12	.715	.715	3.825
54164	3	3.87	11.61		24	.715	2.145	8.301
54S280	5	19.43	97.15		40	.715	3.755	72.960
DM8160	2	3.20	6.40		20	.715	1.43	4.576
9386	3	1.61	4.83		24	.715	2.145	3.453
Resistors	3	.03	.09		15	.013	.039	.001
PC Board	1	5.00	5.00		25	-	-	-
Board Process	1	-	-	485		-	-	-
Cut and Swage	1	-	-	333		-	-	-
TOTALS			140.14	818	224 x 1.7 = 381		12.544	$\frac{95.960}{12.544}$ = 7.65

SYSTEM 4096 SAB

SUB-ASSEMBLY Power Supply

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N2905A	2	.61	1.22		12	2.498	4.996	3.048
2N3054	1	.82	.82		6	3.749	3.749	3.074
2N1613	4	.60	2.40		24	1.266	5.064	3.038
2N3740	2	1.20	2.40		12	2.498	4.996	5.995
2N3055	1	1.05	1.05		6	3.749	3.749	3.939
1N4002	9	.12	1.08		45	.155	1.395	.167
1N4740	1	.38	.38		5	.4	.4	.152
1N4736A	2	.41	.82		10	.4	.8	.328
1N4734A	2	.41	.82		10	.4	.8	.328
1N4719	2	.35	.70		10	.358	.716	.251
1N754	2	.60	1.20		10	.4	.8	.480
1N4562B	1	5.65	5.65		5	.4	.4	2.260
1N4735A	1	1.40	1.40		5	.4	.4	.560
1N4005	1	.42	.42		5	.361	.361	.152
1N4454	1	.13	.13		5	.155	.155	.020
Transformer	1	11.00	11.00		615	1.5	1.5	16.50
3jX37B	2	.75	.75		50	.651	1.302	.977
Potentiometer	3	3.00	9.00		45	.664	1.992	5.976
Cap-T/E	15	.18	2.70		75	.55	8.25	1.485
Cap-Disc	2	.05	.10		10	.291	.582	.029
Resistor-Film	14	.15	2.10		70	.046	.644	.097
Resistor-FC	12	.03	.36		60	.013	.156	.005
TOTALS								

Continued

SHEET 14 OF 16

SYSTEM 4096 SAB

SUB-ASSEMBLY Power Supply

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Fuse	2	.37	.74		20			
PC Board	1	5.00	5.00		10			
Misc. Hardware	Lot	2.00	2.00		100			
Board Process				485				
Cut and Swage				333				
TOTALS			54.24	818	1225x1		43.207	$\frac{48.857}{43.207} = 1.13$

SYSTEM 4096 SAB

SUB-ASSEMBLY Chassis

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cable Assembly	1				1000			
Conn. Plug	2	2.50	5.00		50	1.342	2.684	6.710
Chassis Assembly	1							
Cover	1	13.00	13.00	1365	684			
Front Panel	1							
RF Cables	Lot	.50	.50		150			
RF Conn.	5	1.25	6.25		50	1.128	5.64	7.050
Misc. Hardware	Lot	6.50	6.50		250			
Conn. ARINC	2	11.97	23.94		1000	1.342	2.684	32.127
PC Conn.	6	1.67	10.02		600			
Wiring	Lot	1.50	1.50		1000	6.3	6.3	9.450
TOTALS			66.71	1365	4784		17.308	$\frac{55.337}{17.308} = 3.20$

SYSTEM 4096 SAB

SUB-ASSEMBLY Final Assembly

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Transmitter	1				60			
Receiver	2				50			
IF Amplifier	2				50			
Video Proc.	1				50			
Control Matrix	1				50			
Monitor					75			
Power Supply	1				190			
Comparator Card	1				50			
Decoder Card					50			
ATCRBS Decoder					50			
ATCRBS Encoder					50			
Chassis	1				150			
Func. Test					2000			
Burn-In					1000			
TOTALS					3875			

SYSTEM SAB Transponder-GA

SUB-ASSEMBLY Transmitter

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cavity Oscillator	1	21.	21.		250	200.	200.	4200.
Resistor	1	.10	.10		5	.03	.03	.003
2N2222	1	.40	.40		6	1.266	1.266	.506
IN4153	2	.30	.60		10	.155	.31	.093
IN4735	1	.30	.30		5	.4	.4	.12
GP RECT. - HV	2	.25	.50		10	.358	.716	.179
Transformer	1	.50	.50		315	2.309	2.309	1.155
Transistors	2	.65	1.30		12	2.498	4.996	3.247
Potentiometer	1	.29	.29		15	.664	.664	.193
Coil - 100mh	3	.43	1.29		18	.069	.207	.089
Cap - Mylar	3	.16	.48		15	.55	1.65	.264
Cap - Disc	9	.12	1.08		45	.291	2.619	.314
Resistors	9	.02	0.18		45	.013	.117	.002
PC Board	1	3.00	3.00	793	25			
TOTALS			31.02	793	776		215.284	$\frac{4206.}{215.3} = 19.54$

SYSTEM SAB Transponder - GA

SUB-ASSEMBLY Receiver

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
LP Filter	1	1.50	1.50		250	11.844	11.844	17.766
BP Filter	1	3.50	3.50		250	1.18	1.18	4.13
Tuned CKT	1	.75	.75		25	.475	.475	.356
Coils	23	.06	1.38		138	.069	1.587	.095
Cap-M/T	28	.15	4.20		140	.55	15.4	2.310
Cap-Disc	36	.05	1.80		180	.291	10.476	.524
Cap-Var	1	.92	.92		15	1.58	1.58	1.454
IF Trans.	4	.75	3.00		160	.475	1.9	1.425
Resistor FC	55	.03	1.65		275	.013	.715	.021
Potentiometer	3	.29	.87		45	.664	1.992	.578
Crystal	1	1.50	1.50		15	.226	.226	.339
IN4153	1	.30	.30		5	.155	.155	.047
IN4154	1	.25	.25		5	.155	.155	.039
FD777	1	.98	.98		5	.155	.155	.152
FH1100	1	.33	.33		5	.155	.155	.051
2N3646	1	.65	.65		6	1.266	1.266	.823
2N5086	2	.45	.90		12	2.124	4.248	1.912
SKA4580	4	.65	2.60		24	1.266	5.064	3.292
2N2222A	1	.40	.40		6	1.266	1.266	.506
MPS6515	1	.39	.39		6	1.266	1.266	.494
PC Board	1	3.00	3.00	793	25	-	-	-
Chassis	1	1.50	1.50	20	25	-	-	-
TOTALS			32.37	813x2 = 1626	1617x2 = 3234		61.105	$\frac{36.314}{61.105} = .59$

ITEM SAB Transponder - GA

SUB-ASSEMBLY Main PC Board

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MC9715P	1	.95	.95		8	.12	.12	.114
MC724P	1	.81	.81		8	.12	.12	.097
7400	2	.35	.70		16	.12	.24	.084
9093	5	.54	2.70		40	.715	3.575	1.931
9949	1	.35	.35		8	.12	.12	.042
930	7	.35	2.45		56	.24	1.680	.588
932	1	.35	.35		8	.24	.24	.084
936	1	.43	.43		8	.21	.21	.090
946	4	.35	1.40		32	.12	.48	.168
2N5134	15	.24	3.60		90	1.266	18.990	4.558
2N5133	1	.23	.23		6	1.266	1.266	.291
2N5139	4	.13	.52		24	2.124	8.496	1.104
2N5138	3	.23	.69		18	2.124	6.372	1.466
2N5128	1	.23	.23		6	2.124	2.124	.489
2N4916	1	.16	.16		6	2.124	2.124	.340
2N3391	1	.24	.24		6	1.266	1.266	.304
2N5308	1	.35	.35		6	1.266	1.266	.443
2N3567	1	.24	.24		6	1.266	1.266	.304
2N4870	1	.50	.50		6	1.662	1.662	.633
2N5494	1	.70	.70		6	1.266	1.266	.886
2N5172	2	.12	.24		12	1.266	2.532	.304
2N2405	1	.87	.87		6	1.266	1.266	1.101
TOTALS								

Continued

SYSTEM SAB Transponder - GA

SUB-ASSEMBLY Main PC Board

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SD445	2	.76	1.52		12	2.124	4.248	3.228
Diode, Silicon	14	.12	1.68		70	.155	2.170	0.260
Diode, Zener	1	.43	.43		5	.4	.4	.172
Choke	3	1.71	5.13		45	2.12	6.360	10.876
Coil, Adj.	1	.43	.43		40	.475	.475	.204
Coil	1	.06	.06		6	.069	.069	.004
Capacitor-Disc	53	.06	3.18		265	.291	15.423	.925
Capacitor-M/T	21	.18	3.78		105	.55	11.550	2.079
Capacitor-Var	1	.92	.92		15	1.58	1.58	1.454
Resistor	118	.03	3.54		590	.013	1.534	.046
Potentiometer	8	.29	2.32		120	.664	5.312	1.540
Transformer-Pwr.	1	6.95	6.95		415	1.500	1.500	10.425
PC Board	1	5.00	5.00		25	-	-	-
Board Process	1	-	-	485		-	-	-
Cut and Swage	1	-	-	333		-	-	-
TOTALS			53.65	818	2095 x 2.5 = 5238		107.302	$\frac{46.634}{107.302} = 0.44$

SYSTEM SAB Transponder - GA

SUB-ASSEMBLY SAB Decode and Processing

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
7400	1	.35	.35		8	.12	.12	.042
7404	2	.43	.86		16	.21	.42	.181
7408	2	.37	.74		16	.14	.28	.104
7411	2	.37	.74		16	.105	.21	.078
7420	1	.35	.35		8	.24	.24	.084
74H21	1	.41	.41		8	.07	.07	.029
7432	1	.49	.49		8	.12	.12	.059
74107	4	.54	2.16		32	.715	2.86	1.544
74154	1	2.04	2.04		12	.715	.715	1.459
74161	2	1.07	2.14		20	.715	1.43	1.530
74164	3	1.42	4.26		24	.715	2.145	3.046
74S280	5	4.38	21.90		50	.715	3.575	15.659
LM319	1	3.00	3.00		8	.715	.715	2.145
DM8160	2	2.56	5.12		20	.715	1.43	3.661
MC7242	3	1.40	4.20		24	.715	2.145	3.003
IN4148	1	.13	.13		5	.155	.155	.020
Capacitor-Disc	2	.06	.12		10	.291	.582	.035
Resistor	11	.03	.33		55	.013	.143	.004
PC Board	1	5.00	5.00		25	-	-	-
Board Process	1	-	-	485		-	-	-
Cut and Swage	1	-	-	333		-	-	-
TOTALS			54.34	818	365 x 2.5 = 913		17.355	$\frac{32.683}{17.355} = 1.88$

SYSTEM SAB Transponder

SUB-ASSEMBLY Chassis and Enclosure

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Face Plate	1	2.00	2.00	74	50			
Chassis	1	2.00	2.00	184	85			
Cover	1	1.00	1.00	82	40			
Switch-Code	4	1.41	5.64		60	4.419	17.676	24.923
Lamps	2	.35	.70		10			
Switch-Select	1	1.41	1.41		15	4.419	4.419	6.231
Switch-PB	1	.30	.30		15			
Potentiometer	1	.35	.35		15	.664	.664	.232
Connector-RF	1	.75	.75		25			
Connector-Cable	1	1.15	1.15		25			
Preselector	1	6.48	6.48		25			
Misc. Hardware	Lot	2.00	2.00					
TOTALS			23.78	340	365		22.759	$\frac{31.386}{22.759} = 1.38$

ITEM SAB Transponder - GA

SUB-ASSEMBLY Final Assembly

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAILURE RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Transmitter	1				60			
Receiver	1				50			
Main PC Board	1				25			
SAB PC Board	1				25			
Chassis & Encl.	1				100			
Wiring	Lot				200			
Functional Test					2000			
Burn-In					1000			
TOTALS					3460			